MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME LIX.

THE LOWER GONDWANA COALFIELDS OF INDIA. BY CYRIL S. FOX, D.Sc. (Birm.), M.I. MIN.E., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 1 to 14.)

Published by order of the Government of India.

CALCUTTA: SOLD AT THE CENTRAL BOOK DEPÔT, 8, HASTINGS STREET, AND AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA, 27, CHOWRINGHEE ROAD.

DELHI: SOLD AT THE OFFICE OF THE MANAGER OF PUBLICATIONS.

1934.

PREFACE.

Attention is called to the title of this memoir to indicate that the coal measures of the Mesozoic era (including the Upper Gondwanas and the so-called Upper Cretaceous coalfields), and particularly the Tertiary coalfields of Assam, Baluchistan, Burma, Kashmir, the Punjab and Rajputana, are not discussed in the following pages. As it is, the details given in regard to the Lower Gondwana coalfields of India have made this memoir, Volume LIX, larger than was at first intended. The coalfields of the Mesozoic and Tertiary strata will be dealt with fully in another memoir, Volume LX of the *Memoirs of the Geological Survey of India*, which is to be published shortly.

No less than 80 separate coalfields have been recognised among the Lower Gondwana coal-bearing outcrops in various parts of India. In many cases, these are clearly the exposed measures of a great area most of which is covered by somewhat younger Gondwana rocks. In the case of the Satpura region, the coal measures are thought to lie at too great a depth to work in most of the tracts covered by younger Gondwana rocks. In the Wardha-Godavari area, the cover of younger Gondwanas is relatively thin, but there has been a pre-Kamthi period of erosion whereby, in many areas, the coal measures are now missing and thus exploration through the younger rocks is somewhat uncertain.

It was thought that the Damudas of the Himalayan region in Bengal and Assam, being inverted, might be found under the alluvium of the Ganges in Bengal and the Brahmaputra in Assam. The exposures of gneisses in the Assam valley north of the Brahmaputra, however, is suggestive of considerable erosion before the alluvium was laid down. Further, the southern boundary faults along the base of the Himalaya in Assam and Bengal must be thrust-planes whereby the Gondwanas in the hills have been driven southward on to older rocks. Thus the hopes of concealed coalfields in the Ganges valley are probably false.

There can be no doubt that the Damuda strata of the Darjeeling Himalaya and the Bhutan and other eastern tracts of the same great range were laid down as part of the Damudas of the Bengal and Bihar coalfields. The discontinuities found to day are due

to dislocations by faulting and mountain uplift and enormous erosion of exposed surfaces since the close of the Palaeozoic era. A small outlier of Damudas found at the western end of the Assam range almost on the banks of the Brahmaputra river, after its southward bend, shows further the complications produced by the causes referred to above. It is believed that a great N. N. W. fault, with a westward downthrow, occurs in the alluvial tracts of Eastern Bengal, between this outlier and the Rajmahal hills.

In connexion with calculations for coal reserves, the experience of the past 75 years has shown that the statement *total workable coal* is of better academic value than that of *available coal*, the latter being usually taken as two-thirds of the former, one-third being assumed for loss in working, faults and similar unavoidable non-recovery. The actual coal obtained is shown in five examples, taken over periods of more than 25 years, to be less than one-fifth of the calculated reserves in the small fields worked by a single colliery company. It has not been possible to make reliable calculations for the larger fields but the evidence suggests that the amount won is about 50 per cent. of the *available reserves*.

In the reports submitted in 1932-33 to the Subsidence Committee of the Mining and Geological Institute of India, most of the contributors showed that the coal taken from their workings was of the order of over 80 per cent. of the worked section of the seams exploited. This percentage of extraction, and even more than 90 per cent., is obtained from the limits of a definite area of working. These are trifling fractions when compared with the total areas of all coal seams and the total thicknesses of the workable coals, which make up the reserves of a whole coalfield. The day has still to come when colliery companies will combine and work a coalfield according to a common efficient plan.

Finally, there is much to be said in regard to the manner of recording the raisings of coal from each colliery and so from the various coalfields. It is not only in the past where only coal despatched by definite railways, or the coal from one colliery, has been included in that of another in a distinct coalfield. These uncertain data make it difficult to keep a correct tally of the coal production annually. In this memoir, at Dr. Fermor's special instigation, I have endeavoured to collect all the data that I could in regard to the total production of coal from each coalfield in India since each was opened or developed. There are many gaps, but

nevertheless the figures obtained are of considerable interest. Since the first field was opened in 1774, not more than 600 million tons of coal have been taken from the coal mines in India up to 1932. The estimated total workable reserves for this country are accepted as of the order of 20,000 million tons. Assuming an extraction of 20 per cent. on the whole the *getable* coal is 4,000 million tons, which, at an outturn of 25 million tons annually, means 160 years supply, irrespective of quality.

If we consider only first class coal, then the total amount of workable coal in this country is of the order of 5,000 million tons and, assuming an extraction of 50 per cent. of the whole, we get first class coal of about 2,500 million tons, which, at an outturn of 20 million tons annually, means 120 years' supply. And if we take the good caking coal reserves as 1,500 million tons and the extraction in working at 50 per cent., then the raisings will amount to 750 million tons. This, at an output of 12·5 million tons annually, means only a sixty-year supply. If the production is increased without any improvement in the percentage extraction, the supplies of good quality caking coal will be nearing exhaustion in less than 50 years.

CYRIL S. FOX.

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CORRIGENDA.

The Kanala coal lease, held by Sir Fazilbhoy Currimbhoy and :ails of the first production of coal from which were received ilst this Memoir was in the Press, has been mistakenly identified th the village Chunala (19° 47′: 79° 24′). Later information, eived when the Memoir was ready for binding, indicates that the se lies within the Tandur coalfield as demarcated by Dr. x on page 321. The necessary corrections should be made on ge xv of the Contents, on pages vii, xvi, xxiii of the Index, and pages 319, 352, 377 and 385.

On page xii of the Contents, *read* "297" and "299" *for* "997" d "292" respectively.

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CHAPTER 1.

INTRODUCTION.

Discovery of Coal in India.

It is believed that coal was known to occur in India long before the country was opened up by European enterprise. The people of the country, however, evidently preferred to use wood and cow-dung, as they do still in many places, than to dig coal. The first coal mines were worked by Messrs. Sumner and Heatly in the Raniganj coalfield near Sitarampur about 1774. Shortly after, in 1777, an effort was made by Messrs. Motte and Farquhar to establish ironworks in the same vicinity. These early developments appear to have been largely due to the personal enterprise of the servants of the Hon'ble East India Company for public use. These activities although encouraged by Warren Hastings, were not sufficiently maintained after his departure from India. The newly established coal industry was practically defunct during the period 1788 to 1814, when the Marquis of Hastings arrived in India. This Governor-General ordered a thorough investigation of the occurrence of coal in this country, which resulted in a revival of the coal industry.

The coal from mines situated near Raniganj and up the Adjai river was taken down the Damodar river to Amta and transported

to Howrah and Calcutta. The laden barges could only travel in the rainy season and then only when the river was in flood. Thus much of the coal that had been mined during the dry months lay exposed to the sun and rain for weeks before despatch. Many cargoes were lost by shipwreck and sometime usually elapsed before stocks in Calcutta were consumed. The transport question steadily became more acute as new localities containing coal were discovered in the Raniganj field and opened. Coal occurrences were also reported from several other areas. The subject of assisting the coal industry thus became one for official encouragement.

Reports of the Coal Committees of 1838 and 1846.

A list of the discoveries of coal, their localities, extent and by whom brought to notice, is given in the report of the Coal Committee in 1837 (published 1838). A Museum of Economic Geology was established in 1840 in Calcutta under the sanction of the Hon'ble the Court of Directors, and H. Piddington, Esqr., of the Asiatic Society, was placed in charge of the collections. Experienced miners were sent out to India to give practical assistance in the opening and working of the mines. By 1842, the total coal output from the Raniganj area was of the order of 50,000 tons. And with the spread of railways in Europe, it was decided to construct the 120 miles of line from Howrah to Raniganj. This was effected in 1845, after which the coalfields of India assumed a new importance.

At this interesting stage the Coal Committee in their report for 1845 (published 1846) had come to the conclusion that the time was ripe for a proper geological investigation. They

'....ventured to recommend a Geological Survey of the Coal formation of India, or at least that this question should be referred to the highest scientific authorities in England'.

These recommendations were approved and forwarded by the Government of Bengal and accepted in London, and Mr. D. H. Williams of the Geological Survey of Great Britain, then mapping the South Wales coalfield, was sent out to India.

Mr. Williams arrived in 1845 and was deputed to examine the Raniganj coalfield. His geological investigation of that area was completed by 1847, and his report was greatly appreciated by the Coal Committee under whom he worked. Later Mr. Williams extended his observations to the Bokaro and Ramgarh coalfields,

and finally he was engaged in the examination of the Karanpura (he called it the Hoharo) coalfield, when he contracted a severe form of jungle fever and died in that part of the Damodar valley in 1848.

Dr. T. Oldham and the Geological Survey of India.

On Mr. William's death Dr. J. McClelland, the Secretary of the Coal Committee, was deputed to carry out the programme drawn up by Mr. Williams. In this way the Rajmahal Hills and the Karharbari (Giridih) coalfield were examined by Dr. McClelland, who submitted a 'Report of the Geological Survey of India for 1848-49', in 1850. Meanwhile in 1851 Dr. T. Oldham, Director of the Geological Survey of Ireland, was induced to come out to India. He found that there was no Geological Survey office other than the Museum of Economic Geology, and that the staff allotted to him consisted of one writer and a peon. With his address and energy and the influence of his well-known name, these shortcomings were soon remedied.

Dr. Oldham's staff increased with the arrival of the brothers J. G. and H. B. Medlicott in 1853, and the brothers H. F. and W. T. Blanford about 1855. By 1856 the coalfields of the Rajmahal hills, the Son and Narbada valleys and Talcher had been carefully examined. And with the coming of Lord Canning (1856) a new era opened for geological research in India. The Geological Survey was established as a proper Government Department, and with it a new Museum of Geology was opened, at 1, Hastings Street, Calcutta, on the 1st January, 1857. The work of the Geological Survey was systematized so that surveys were to be conducted in areas of which topographical maps were available, and the reports began to be published in a uniform series.

After the Mutiny (1857), the surveys of the coalfields were carried on uninterruptedly until 1876 when Dr. Oldham retired in broken health after 25 years of splendid service. By that time the Geological Survey of India had established a great scientific reputation in Europe. Its staff included, besides British geologists, well-known names from Germany, Austria, Bohemia and Hungary. With Dr. Oldham as its foundation and with the Medlicotts, Blanfords, William King (1857), R. Bruce-Foote (1858), F. R. Mallet (1858), A. B. Wynne (1862), T. W. H. Hughes (1862), F. Stoliczka (1862), V. Ball (1864), W. Waagen (1870), R. Lydekkar (1874) and

Ottakar Feistmantel (1875) as its walls and columns the real building up of the Geological Survey was completed. Since then it has been ornamented by equally well-known names—R. D. Oldham (the son of Dr. Oldham), C. S. Middlemiss, T. D. LaTouche, Sir Thomas Holland, Sir Henry Hayden and Sir Edwin Pascoe.

Dr. V. Ball : 'Economic Geology of India', 1881.

During the 25 years of its organised existence (1856 to 1881), not only had the coalfields been examined but a treatise on the Economic Geology of India had been written by Dr. V. Ball and published by Government as Part III of the 'Manual of the Geology of India'. Dr. Ball in his great work (pages 50 to 120) gave a very full account of the various coalfields in this country. His work was, of course, based on his own surveys, but largely included the information obtained from the reports of his colleagues. T. W. H. Hughes, perhaps the pioneer geologist of the Gondwana coalfields, had surveyed and reported on the Jharia[1], Bokaro[2], Giridih[3], Wardha Valley[4], and several other coalfields in the Peninsula.

W. T. Blanford had early submitted his reports on the Talchir[5], and Raniganj coalfields.[6] F. R. Mallet had examined the coalfields of the Western Duars and Darjeeling[7] and of the Naga Hills in Assam.[8] The Medlicotts, Ball, King, and others had investigated or were engaged in surveying the coalfields of the Satpura uplands, the Son Valley tract, the Godavari and other regions. And among his earliest investigations Dr. T. Oldham had visited the coal outcrops of Assam, Burma and the Punjab.

In the Preface of Dr. Ball's 'Economic Geology', Mr. H. B. Medlicott, then Director of the Geological Survey of India, wrote :—

'The geologist has an anxious part to play with reference to practical questions. He is instituted more as a concession to what seems but a rising fashion, than from any faith in his knowledge or any understanding of his functions ; and thus it happens that he is not consulted when his opinion might be of great service, or, on the other hand, he is called in to perform what is quite out of his line of business, or twitted for not having done what it would be unwise to attempt unless under special

[1] *Mem. Geol. Surv. Ind.*, V, (1866).
[2] *Op. cit.*, VI, (1867).
[3] *Op. cit.*, VII, (1871).
[4] *Op. cit.*, XIII, (1877).
[5] *Op. cit.*, I, (1856).
[6] *Op. cit.*, III, (1863).
[7] *Op. cit.*, XI, (1874).
[8] *Op. cit.*, XII, (1876).

circumstances, and impossible to undertake without special appliances that were not at his disposal. As no one is more aware than himself that the best, if not the only, warrant for his existence is his usefulness, such circumstances are very distressing. The martyr's hope is sometimes his only consolation—that there is surely a better time about to dawn, when, knowledge will prevail among the people.'

He continued that

'the Geological Survey of India had its origin in the desire of Government to have the coalfields of this country systematically investigated, and the work of the survey was for some time wholly devoted to this task. It was only after the principal coalfields had been mapped and described, or were well in hand that the general examination of the Geology of India was taken up......What real information we possessed was already published in greater fulness than could be rendered in a summary for the whole of so great an area; and that information related almost entirely to coal and iron; for the rest there were in most cases only dry facts, insufficient for any safe practical judgment......A complete collection of those isolated observations involved long and patient search through many papers published and unpublished. This work has now been very thoroughly accomplished by Mr. Ball: in this 3rd Part of the Manual of the Geology of India, he has colligated all the scattered information in groups of subjects and of districts, indicating the relations to what is known of the geology of the country. The student as well as the man of enterprise will long owe him gratitude for the great store of facts thus brought within easy reference.'

R. R. Simpson : Coalfields of India, 1913.

Thirty-two years after the publication of Dr. Ball's 'Economic Geology', Mr. R. R. Simpson prepared a special memoir on the coalfields of India.[1] Sir Henry Hayden, then Director of the Geological Survey of India, wrote the following Preface:—

'For many years the third part of the *Manual of the Geology of India* (Economic Geology: by V. Ball) has been out of print and several projects have been formed for the publication of a new edition. Under the first of these it was proposed to re-issue the publication in a series of separate volumes, each dealing with a single mineral, and a beginning was made with Corundum (by T. H. Holland) in 1898. It soon became clear, however, that this method of re-editing would extend over a very long period and the question of reproducing a revised manual on the original lines was reconsidered; articles were prepared by various members of the Geological Survey, but pending the completion of the whole volume, were not published; it is hoped that the work will be issued before long in a short form with an extensive bibliography and in the meantime it has been decided to publish such articles as are likely to be of immediate interest. One of these is the article on coal, which was revised by Mr. R. R. Simpson, now Inspector of Mines, while he was still attached to the staff of the Geological Survey: this he has now further revised and brought up to date......'

[1] *Mem. Geol. Surv. Ind.*, XLI, (1913).

Within five years of its appearance, Mr. Simpson's memoir on the Coalfields of India was practically out of print. It had proved of considerable value to those who were commercially as well as geologically interested in the Indian coalfields. The decision to issue a second edition—almost unprecedented in a Government publication—was made by Sir Henry Hayden. And he wrote a new Preface as follows :—

'Seven years ago, Mr. R. R. Simpson, who had left the Geological Survey of India to join the Department of Mines a short time before, kindly undertook, with the approval of the Chief Inspector of Mines and in addition to his own duties, the preparation of this memoir, partly from materials collected by himself during his earlier service as a member of the Geological Survey, and partly from materials already published in the third volume of the Manual of the Geology of India by Dr. V. Ball. The value of Mr. Simpson's work has been proved by the fact that the memoir is already out of print. The progress in the development of the coal mines of India and in various allied industries in recent years has been more than sufficient to warrant a treatise more commensurate in size with the importance of the subject. It is hoped that, at some future and not very distant date, such a task will be taken up by the Geological Survey Department, but this reprint is issued to fill the present interval and to satisfy a continued demand for information on this subject. The three maps published in the first edition have been reproduced, but it has not been thought necessary to reprint the pictorial illustrations.'

Re-examination of the Coalfields of India, 1925-30.

The hope expressed in the above Preface by Sir Henry Hayden in 1921, has been fulfilled by his successor Sir Edwin Pascoe. He decided in 1924 that the time had come for the coalfields to be re-examined and a new memoir prepared with up-to-date information. He deputed me to carry out the work. My field investigations have included visits to every coalfield in India which is being explored. In most cases I spent but a few days at each in order to get information and check the older geological maps by field surveys. In the case of the Jharia and Raniganj coalfields, detailed surveys of both areas have been carried out on maps to the scale of four inches to the mile. In the former area, I mapped the whole field alone. In the Raniganj field, the surveys were carried out by a party working under my orders. This party consisted of the late Rai Bahadur Sethu Rama Rau, Mr. E. R. Gee, Rai Bahadur A. K. Banerjee and Mr. J. B. Auden of the Geological Survey of India. The Pench Valley, Kanhan and Tawa Valley coalfields in the Chhindwara and Betul districts of the Central Provinces, have also been surveyed by me. I was assisted

in the former district by Messrs. G. V. Hobson and W. D. West and in the latter district by Mr. E. R. Gee. Mr. G. V. Hobson has also surveyed one of the coalfields (Pachwara) in the Rajmahal hills. Dr. J. Dunn has surveyed the Aurunga and Hutar coalfields in the Palamau district of Bihar and Orissa.

I had in earlier years visited the Aurunga and Hutar coalfields; and also the Korea and Sirguja (Bisrampur and Jhilmilli) coalfields. The only fields I have not yet visited are those of Jammu (Kashmir), the Eastern Himalaya (beyond the Darjeeling district) and Lower Burma. I have of course had access to the field notes and maps of various colleagues who have at one time or another examined parts of some coalfields. I am grateful to Dr. L. L. Fermor for his information on the geology of the eastern and western areas of the Bokaro coalfield.

The information collected by these new surveys and visits to the various Indian coalfields is considerable. For the Jharia and Raniganj coalfield it was best to write separate memoirs. This has been done for the former field by myself[1] and for the latter by Mr. E. R. Gee.[2] And during recent years a new memoir has been published on the Karanpura coalfields.[3] These three important coalfields have already been dealt with in detail: for which reason I have not considered it necessary to discuss them so fully in this memoir. It is not possible to bring the whole of the new facts and other data within the compass of a single memoir. I have therefore discussed the coalfields of India in two main groups:—(1) The Lower Gondwana coalfields and (2) the Mesozoic and Tertiary coalfields. To make each as complete as possible, I have mentioned the Upper Gondwana coal occurrences in the memoir dealing with the Lower Gondwana coalfields.

[1] *Mem. Geol. Surv. Ind.*, LVI, (1930).
[2] *Op. cit.*, LXI, (1932).
[3] *Op. cit.*, LII, Pt. 1, (1925), by Dr. A. Jowett.

CHAPTER 2.

GEOLOGY.

Geological Occurrence of Coal in India.

No workable coal has been found in strata older than the base of the Damudas (Permian)--the so-called Karharbari stage of the Barakar series of India. Carbonaceous shales occur in far older strata and have in past years given rise to hopes for coal, but no seam of coal worth exploitation has yet been found in formations older than the Barakars. On the other hand coal or lignite has been found in almost every other formation younger than the Barakars within the limits of British India or the Indian States associated with it. The coal occurrences in formations younger than the Damudas will be dealt with in detail in the next memoir.[1] However, the geological succession of strata in which seams of coal of workable thickness and quality have been found in this country is given below: –

System.	Series.	Occurrence.
	Pleistocene	Lashio and Namma (Burma).
	Pliocene	Karewa (Kashmir).
	Miocene	Shwebo and Wunthu (Burma).
	Oliogocene (?)	Makum (Jaipur) and Nazira (Assam).
	Upper Eocene	Yaw river, Kalewa, etc. (Burma) and Cherrapunji and Lakadong (Assam).
	Middle Eocene	Garo, Khasi and Jaintia Hills (Assam).
	Lower Eocene	Jammu, Dandot, Khost, Palana, etc.
Cretaceous	Upper Cretaceous.	
	Lower Cretaceous	Umia beds (Cutch).
Jurassic	Upper Oolite	Jabalpur beds of Lameta Ghat, Hard river and Lokartalai (C. P.).
	Lower Oolite	Loi-an (Kalaw) field, Southern Shan States.
	Lias.	
Triassic	Keuper.	
	Bunter.	
Lower Gondwana	Raniganj	Damodar valley and Tawa valley.
	Barren Measures.	
	Barakar	Most Gondwana coalfields in India.
	Talchir.	

The present memoir deals with those coalfields in which the seams occur in strata belonging to the Gondwana system. By far

[1] *Mem. Geol. Surv. Ind.*, LX.

the greater number of these coal occurrences are in beds of Damuda (Permian) age, *i.e.*, restricted to the Lower Gondwanas. The most extensive, as also the most prolific, period of coal formation in the Indian region is that represented by the deposits of the Damuda sub-system, in particular by the earlier portion of it known as the **Barakar** series or the lower coal measures. Coal seams occur in the Raniganj series or upper coal measures in some coalfields. At one time, it was thought that the coal measures in the Darjeeling foot-hills and the Eastern Himalaya were deposits of the Raniganj epoch. This correlation is rendered uncertain by my discovery of a boulder bed above Tindharia station, and it is possible that the Darjeeling and Teesta valley coals belong to the Barakar series.

Coal occurrences in the Upper Gondwana formations are seldom found to be of economic importance. Perhaps the most interesting of these are the Loi-an series in the Southern Shan States of Burma, east and north of the general vicinity of Kalaw (20° 38′ : 96° 37′). These occurrences will be dealt with in detail in the next memoir, which discusses the Mesozoic and Tertiary coalfields of India.[1] Rare occurrences of coal in the Upper Gondwanas are also found in the Satpura region of the Central Provinces, in the Hard river, and at Lokartalai. The strata belong to the Jabalpur series and are of Upper Jurassic age. Coal has also been noted in the Chikiala beds of the Wardha valley. These strata are considered as probably of Middle Jurassic age. Thin and poor coal has been found in the Umia beds of Cutch (Kachh) in strata considered to be at the top of the Gondwanas and to be Portlandian to Neocomian in age (*i.e.*, passage beds between the Jurassic and Cretaceous systems).

Gondwana System.

A special memoir[2] has been prepared, in which the formations and their distribution in India are dealt with. It is there shown that the Gondwana era began, with a glacial period, in Upper Carboniferous times and closed at the beginning of the Cretaceous period. It is also shown that this vast range of time can be divided into two chief periods—an older (lower) characterised by the so-called *Glossopteris* flora, and an upper characterised by a cycadaceous *Ptilophyllum*

Upper and Lower Gondwanas.

[1] *Mem. Geol. Surv. Ind.*, LX.
[2] *Op. cit.*, LVIII, (1931).

flora. The line of division between them is drawn about the middle of the Triassic period when hot desert conditions appear to have prevailed in the Indian region. It is in this hiatus that the *Glossopteris* or Damuda flora seems to disappear and after which the *Ptilophyllum* or Rajmahal flora becomes predominant.

The Gondwana system in the Indian Peninsula comprises the following formations :—

	Lower Cretaceous	Umia plant beds		Upper Gondwanas
Jurassic	Upper Jurassic	Jabalpur stage		Upper Gondwanas
Jurassic	Middle Jurassic	Kota stage		Upper Gondwanas
Jurassic	Lower Jurassic	Rajmahal (inter-trappean) plant beds		Upper Gondwanas
Trias	Rhaetic	Bagra, Denwa stage	Mahadeva series	Upper Gondwanas
Trias	Keuper	Pachmarhi	Mahadeva series	Upper Gondwanas
Trias	Bunter	Panchet series		
Permian	Upper Permian	Raniganj series	Damudas	Lower Gondwanas
Permian	Middle Permian	Barren Measures	Damudas	Lower Gondwanas
Permian	Lower Permian	Barakar series with Karharbari stage and Umaria marine beds	Damudas	Lower Gondwanas
	Upper Carboniferous	Talchir series with glacial boulder beds		Lower Gondwanas

Practically the whole of the true coal-bearing Gondwana sediments appear to have been laid down in fresh-water either in large lakes or in wide river valleys. This is almost strictly true of the Indian peninsula as shown by geographical diagrams in the memoir already referred to above. A northern sea extended into the peninsular area in the Barakar epoch, and it certainly existed round the Indian region in the Punjab and Burma areas at the same time. The presence of oceanic conditions at a later time (Trias) is also indicated from marine strata in the Himalaya and Upper Burma. A Jurassic sea is definitely established as having extended from Burma into the area now occupied by the Bay of Bengal. However, Peninsular India evidently remained dry land, but with extensive lakes or wide rivers (very restricted during the Triassic period) throughout the Gondwana era. It has not been possible to demarcate the coasts of the Gondwana lands, but it is clear that the shore-line varied considerably during successive epochs since the southern continent was ice-bound in Talchir times.

Having thus briefly recognised only an Upper and Lower Gondwana subdivision of the great system, and stated that there are no just or stratigraphical reasons for recognising a Middle Gondwana period as has been done in some student text-books, we may

now outline the character of the sediments which comprise the coal-bearing formations of the Lower Gondwana period. These strata have been simply subdivided into the following series and stages in the type area—the Damodar Valley coalfields—of India :—

Lower Gondwana Succession.

Series.	Stages (Raniganj and Jharia).		
Panchet series	Hirapur stage Maitur stage	Not represented	
	Slight unconformity.		
Raniganj series, 3,300 feet	Kumarpur sandstones	Lohpiti sandstones	Raniganj series, 1,840 feet
	Nituria coal-measures	Telmucha coal-measures	
	Hijuli sandstones	Jamdiha sandstones	
	Sitarampur coal-measures	Murilidih coal-measures	
	Ethora sandstones	Mahuda sandstones	Barren Measures, 2,080 feet
Ironstone Shales, 1,200 feet	Ironstone (Kulti) shales	Hariharpur carbonaceous shales	
Barakar series, 2,100 feet	Begunia sandstones	Petia sandstones	
	Begunia shales	Shibbabudih shales	
	Begunia seam	Sitanala seam (No. XVIII)	Barakar series, 2,000 feet
	Laikdih seam, etc.	XV to XIII seams, etc.	
	Damagaria seam	Muraidih (1) seam	
	Unconformity in which Karharbari stage may be missing, also the Umaria marine beds of South Rewah and the Rikba plant beds of Karanpura.		
Talchir series	Talchir needle shales Talchir boulder bed		
	Great unconformity.		

Talchir series.

Although the most sought-for of the Talchirs rocks is the curious boulder bed, the commonest and most characteristic strata are the greenish splintery (needle) shales and the greenish-buff coloured earthy sandstones and trappoid shales. The greatest thickness of the Talchir series is not more than 1,000 feet, while the thickness normally is much less. The boulder bed, which generally occurs near the base of the series, is probably never more than about 50 to 60 feet. These Talchir rocks, especially the needle shales and sandstones and trappoid shales, have been found in almost every area where the coal-bearing Damudas occur. They overlie rocks of far greater age quite discordantly and are in turn almost always overlain by the Damudas with a slight unconformity. In places, as in the Betul district near Sonada and the Shahpur coalfields, there appears to be perfect con-

formability between the upper beds of the Talchirs and the basal beds of the Barakars.

The glacial origin of the Talchirs as a whole has never been insisted on. Even in the case of the boulder bed, such an origin would be doubtful in many areas. It has been only by the discovery of striated boulders, occasionally of facetted pebbles and more rarely of glacial pavements, that the truth has been forced upon the experienced observer. And then only in the case of the boulder bed, which itself is often seen to be faintly bedded as though a moraine had been subsequently water-sorted by flood action. I have stated elsewhere[1] that *the true Ice Age of Gondwanaland was earlier than the Talchir deposits as we find them to-day.*

Plant fossils have been found in beds which even a sceptic must regard as lithologically Talchir in type. Such occurrences are always at the top of the series and well above the boulder bed. The best occurrence of the kind is that near Rikba in the Karanpura coalfield.[2] Here these plant beds are clearly conformably below Barakar strata, but there is a hiatus below between the Rikba plant beds and the boulder bed a few yards from them. Again, in the Sonada coalfield near the village of Kuppa (22° 14′ : 77° 46′) in the Betul district, plant fossils occur in beds which I consider typical Talchirs and which appear to be conformably below coal-bearing Barakars. It is thus seen where suitable sections can be studied that the relationship of the Talchir to the Barakars is both floral and lithological. In none of these occurrences in the Talchirs have any seams of coal of economic thickness or quality been found.

Karharbari stage.

The flora of the Rikba plant beds was considered by Dr. Ottakar Feistmantel as identical with that obtained from the lower coal measures of the Giridih (Karharbari) coalfield. And he and many later palæontologists have insisted that the coal seams and associated strata of the lower measures of Giridih should be regarded as Talchirs.

It is a simple matter to decide that the plant beds are of the Talchir type at Rikba and also at Kuppa. The hiatus at the Rikba exposure is clearly due to a fault which separates the boulder bed from the plant horizon. In the Giridih area, there is an unconformity between the coal measures and the underlying true Talchirs,

[1] *Mem. Geol. Surv. Ind.*, LVI, p. 24, (1930).
[2] *Pal. Ind.*, Ser. XII, Vol. IV, Pt. 2, pp. 2-3, (1886).

and, in addition, the strata above and below this horizon are lithologically quite dissimilar. In the Giridih coalfield, it is not possible by field mapping, to separate the Karharbari coal measures with plant fossils of the so-called Talchir flora from the overlying Barakar coal measures with a typical Damuda flora. And taking into consideration the fact that many of the fossils are also common to both the Karharbari and the Damudas, I have for practical reasons grouped the lower coal measures of the Giridih coalfield with the Barakars.

Dr. Feistmantel was also of the opinion that the lower coal measures of Giridih were represented in the Hutar, Umaria, Mohpani and Shahpur coalfields, because many of the plant fossils common to the Karharbari beds were also found in these areas. If his insistance on this point had been upheld by my colleagues, they would have concluded that no Barakars at all are present in the places named. This, of course, they do not agree with, and in the Hutar and Karanpura coalfields, the evidence suggests a lateral passage from the Karharbari types to typical Barakar plant fossils. It seems to me that it is safer to include the Karharbari stage with the basal Barakars, seeing that workable coal seams occur in both and that many of the fossils are common to both. The Talchirs, on the other hand, have been recognised on lithological evidence of a very characteristic kind which is quite clear in the Giridih field itself. This, plus the fact that there is an unconformity between the Talchirs and lower coal measures in the Giridih area, is my final reason for placing the Karharbari beds in the Barakars.

Barakar series.

The rocks are best developed as a coal-bearing formation in the Jharia coalfield, where they are roughly 2,000 feet thick, according to the stages recognised in my memoir.[1] Even in the Raniganj (western area) coalfield, their thickness, according to the subdivisions recognised by Mr. E. R. Gee[2], are not more than 2,100 feet. It is true that there are one or two little coal seams above No. XVIII seam, my upper limit in the Jharia coalfield, but they are not of economic importance. And we are all in agreement that the Barren Measures are really a conformable upward part of the lower coal measures or Barakar series. No. XVIII seam is a good horizon, as is also the Chanch Begunia seam of the Raniganj coalfield.

[1] *Mem. Geol. Surv. Ind.*, LVI, (1930).
[2] *Op. cit.*, LXI, p. 109, (1932).

For the sake of those who are interested in the typical plant fossils which occur in association with the coal measures of the Damudas, a few varieties are figured on Plates 13, 14, 15 and 16 of the previous memoir (Volume LVIII). On the first two plates (13 and 14) are shown those which give unmistakable evidence that the strata involved are true Damudas, containing a *Glossopteris* flora. On the other plates (15 and 16) are shown typical fossils from the Rajmahal series which indicate a *Ptilophyllum* flora. These latter forms are, of course, those which should warn the discoverer that the beds are not Damudas and, therefore, unlikely to contain workable seams of coal. As regards the Damuda plant fossils it is found that the commonest kinds in the Barakar series are *Gangamopteris cyclopteroides* (in the lower horizons), *Glossopteris indica*, *Glossopteris communis*, *Vertebraria indica* and *Sphenophyllum speciosum*. *Schizoneura gondwanensis*, *Glossopteris conspicua*, *Vertebraria indica* and *Sphenopteris hughesi*, are more characteristic of the Raniganj series.

Damuda plant fossils.

Where the Barakars are seen in close association with the Talchirs in extensive exposures in open country, as in the north-eastern parts of the Jharia coalfield —particularly the section along the fork of the road from Dhanbad to Jharia and Katras—, the difference between the fawn to yellowish arenaceous Barakar strata, with their occasional carbonaceous layers, and the earthy greenish beds of the Talchirs is very evident. Pebbly sandstones are also common in the Barakars, some of which are immediately above seams of coal. Owing to the numerous bands of sandstones, the shaly layers and fire-clays are not always well seen. Such beds are, however, common in most good stream-sections. In the Jharia coalfield, the Barakars contain upwards of 24 seams of coal of greater thickness than three feet. At least 21 seams of greater thickness than five feet are recognised and have been worked in one part of the coalfield or the other. At the least, there must be quite 240 feet of coal (total) in the 2,000 feet of the Barakars in this area.

In the other Damodar Valley coalfields, the strata are similar although the number and total thickness of the beds, including the coal seams, are less than in the Jharia field. Further away in the Son valley and South Rewah basin, in the Satpura region, the Wardha valley and the Orissa tracts, the Barakars are very much thinner and only three or four, or perhaps five, seams of coal

of workable thickness (estimated at five feet if the quality is good) have been found. Beds of coal, carbonaceous shale and shaly coal from 75 to over 100 feet have been noted in several localities in India in these Barakar measures, *e.g.*, near Nardkarki in the Jharia field, the Kargali seam of Bokaro, the Korba seam of the Hasdu valley, etc. In some areas, as in the Pench Valley field, it is not possible to say whether the seams worked in different places are the same or different seams. For further particulars regarding the character of these Barakar coals, the reader is referred to *Memoirs of the Geological Survey of India*, Volume LVII, (1931), and to the coalfield concerned discussed in this memoir in later chapters.

Barren Measures: Ironstone Shales and the Motur horizon.

The Barakars of the Damodar Valley coalfields pass upwards conformably into a series of strata which are somewhat less arenaceous and are devoid of workable seams of coal. Carbonaceous shales and even thin coal seams are present, but none of these have been found useful enough for exploitation. There is, however, in the Raniganj coalfield a thick (1,200 feet) belt of shales with subordinate sandstones with siderite layers in the shales. When exposed to weathering, the sideritic material suffers oxidation with the formation of limonite and liberation of *kankar* (nodules of carbonate of lime). With further weathering, the limonite dehydrates to hematite which lies on the outcrops in scattered pieces. This iron-ore was at one time used at the Barakar Ironworks (now the Bengal Iron Co., Ltd.) at Kulti for reduction to pig-iron. It was for this reason that that belt of shales was called the Ironstone Shales. As the original name is misleading, I have suggested they might be named the Kulti shales.

The Ironstone (Kulti) Shales of the Raniganj coalfield have been correlated with similar beds (the Hariharpur carbonaceous shales) in the Jharia coalfield, where their thickness is roughly 200 feet. In this coalfield, the strata, nearly 2,100 feet, between the top seam (workable) of the Barakar series and the basal seam of the Raniganj series, have so far proved valueless in workable coal seams and fire-clays and iron-ore and have, therefore, been termed the Barren Measures. These Barren Measures are recognisable in the Karanpura field higher up the Damodar valley. Beyond the limits of the Damodar valley, the Barren measures cannot be separated from the overlying Raniganj series because the latter are also devoid of

workable coal seams. Furthermore, there appear to be no special fossils which are characteristic of the Barren Measures.

In the Satpura Gondwana basin, however, where both the coal-bearing Barakar series and the upper or Raniganj series (the Bijori horizon of Medlicott) have been recognised in a great thickness of Damuda strata, not less than 5,000 feet thick, the intervening beds were referred to as the Motur horizon.[1] These Motur rocks are entirely barren of coal and even of carbonaceous material. And the name was extended, under the term Motur group, to the red clays, with calcareous nodules, and brownish sandstones which overlie the Barakars of the Pench valley. The description of these supra-Barakars of the Pench valley[2] has usually been taken as typical of the Motur strata as a whole. In a recent investigation of the Damudas of the Tawa valley in Betul and in the hills of the ridge of Gof Tarai and the deep valley south of it, which is westward from the Motur plateau, I found a conformable sequence from the Talchirs to the coaly horizon of the Bijori series.

The Damudas of the Satpura region are, as a rock formation, as well developed as their equivalents of the Damodar valley without, of course, the same richness in coal measures. There was an almost entire absence of red clays in the Tawa sections and in the adjacent valleys. The beds consist largely of brownish to cream-coloured sandstones and buff to greenish-buff clays of a Talchir-like aspect along that belt which are regarded as Moturs or Middle Damudas, *i.e.*, equivalent to the Barren Measures of Jharia. These clays are frequently calcareous in the lower horizons. Exactly similar beds are exposed in the small exposure of the inlier seen east of Motur (22° 17′ : 78° 37′). The village itself is situated on Deccan trap. In a few places in the upper Tawa valley, in some exposures where the clays had clearly been subjected to prolonged oxidation and wet conditions, a red colour has been induced. In the Pench valley, an extensive outcrop of these clays has been exposed to similar conditions of weathering and the clays are often a bright red colour and are associated with nodules of *kankar*.

It is thus clear that the description of the supra-Barakars of the Pench valley, which are merely the basal beds of the Motur series, is misleading if applied to these Middle Damudas as a whole. Furthermore, although the original brief description given by H. B.

[1] *Mem. Geol. Surv. Ind.*, X, p. 161, (1873).
[2] *Op. cit.*, XXIV, pp. 46-50, (1887).

Medlicott still holds good, the description given by E. J. Jones subsequently (and given in the 2nd Edition of the Manual) refers more particularly to the strata in the Pench valley and thus to beds which have been considerably modified by long weathering. The various shades of colour from red to greenish buff can be seen in several exposures in the sections visible in the hills bordering the Pench valley to the north. As no red clays are seen in the inlier section near Motur, nor in the good exposures in the Tawa valley, I felt that the term Motur series could safely be dropped and the name Barren Measures substituted; but long usage of the name renders this undesirable. At a horizon in sandstones above the basal clays of the Pench valley, the Moturs or Barren Measures yield silicified fossil wood of the *Dadoxylon* type. These were first found by Mr. J. Warde of Junnerdeo Colliery and others have since been found by me. I have also found the same kind of fossil wood at the same horizon in the Tawa valley, where no red clays occur.

In general, however, it is impossible to fix a good line of separation between the Upper (Raniganj series) and Lower (Barren Measures) Damudas outside the limits of the Damodar Valley area. For example, a good deal of confusion arose in the South Rewah area where the supra-Barakars of Damuda age were even confused with strata which, on a lithological aspect, were considered to belong to the Upper Gondwanas. The plant fossil evidence—*Vertebraria* and *Glossopteris*—shows that the beds of Pali and Daigaon of that area are of Raniganj age, so that between them and the Barakars of the Johilla river, there is a gap for the Barren Measures. In any case, the time interval must be recognised. The red colour of the supra-Barakars of South Rewah has been induced long after their original deposition. The grey colour of the unaltered beds has been seen, when the superficial 20 feet is passed through, either by boring or in deep stream-channels.

Raniganj series: Bijoris, Kamthis, Pali and Hingir beds.

The type area of these rocks is the Raniganj coalfield, which has recently been described in detail by my colleague, Mr. E. R. Gee.[1] According to him[2] and following Dr. Blanford's classification, these rocks have a total thickness of 3,400 feet. By my classification, they are here 2,800 feet thick as compared with 1,846

[1] *Mem. Geol. Surv. Ind.*, LXI, (1932).
[2] *Supra.*, p. 109.

feet in the Jharia coalfield. Further west in the Damodar valley, their thickness has not been estimated, but in the Satpura region their equivalents, the Bijoris, must be of the same order of magnitude. In both the Raniganj and Jharia coalfields, they contain valuable coal seams now being worked. In the Raniganj coalfield, especially that portion of it east of the Barakar river in Bengal (Burdwan district), they are the most important coal measures of the field and among the coalfields of India, second only in importance to the Barakar coals of Jharia. Elsewhere the Raniganj series is, as coal measures, of no economic importance (excepting in the Darjeeling district and Eastern Himalaya, where it is not certain whether the coal measures belong to this series).

The series, in its type area, is like the Barakars and consists of sandstones, shales and coal seams. In general the sandstones are finer-textured than those of the Barakars and coarse grits are wanting. Occasional large boulders of a Vindhyan type of sandstone occur in the fine sandstones. It has been suggested that these have been dropped from floating trees—an explanation also advanced for the rare pebbles sometimes found in the coal of the Umaria and other fields. Many of the shales of the Barakars have been found suitable for fire-clays, but this has so far not been proved true for the likely looking shales of the Raniganj series. The coal seams, some 40 feet thick, are also not quite as good in quality on the whole as those of the Barakars of Jharia, but this is partly because they are of a slightly different character being higher in volatile matter and usually containing a larger percentage of moisture. However, such seams as those of Dishergarh are as good as any in India and, on account of their high volatile and long flame characteristics, almost unique for certain purposes.

The fossil plant remains found in these beds are typical Damuda forms—*Glossopteris communis*, *Glossopteris indica*, *Schizoneura gondwanensis*, *Vertebraria indica*, and others are fairly common at certain horizons. And silicified fossil wood *Dadoxylon kumarpurensis* occurs in the upper sandstones (Kumarpur beds in the Raniganj field and in the Lohpiti beds in the Jharia area). It was in the same series, the Bijori horizon in the Satpura region, that the fossil Labyrinthodont remains (of *Gondwanosaurus bijoriensis*) were found by Major Gowan in 1863 near Bijori[1] (22° 22′ : 78° 30′). This is

[1] See also *Pal. Ind.*, Ser. IV, Vol. I, Pt. 4, p. 1, (1885).

the only evidence as yet found in the Peninsula of any vertebrate fauna in the Damudas. As fish remains together with Labyrinthodont fossils, were found in the Gangamopteris beds of the Vihi district of Kashmir by F. Noetling in 1902, it is certain that such animals must have existed in the Indian region during the coal-forming period of the Damudas. Their non-discovery in the coalfields is probably due to insufficient search.

Besides the Satpura region, where the Bijoris represent the Raniganj series, there are several areas where the upper Damudas have been recognised by their plant fossils. Among these are the Kamthis of the Nagpur area (near Bazargaon and Silewada) and of the Wardha valley about Chanda; the so-called supra-Barakars of South Rewah (near Pali); the Hingir beds in the drainage area of the Mahanadi valley; and other un-named beds in the hilly country on the watershed between the Son valley and the Chhattisgarh basin to the south. From an economic aspect, these various rocks have proved disappointing and consequently have not been examined as carefully as they might be at some future date. When it is remembered that they may overlie hidden coal measures at no great depth, a study of them and a search for fossils may be justified at a later period when the country has been opened up.

Almod beds.

The almod beds were recognised by Mr. H. B. Medlicott as forming the topmost beds of Lower Gondwanas and as possibly the representatives of the Panchets of the Damodar valley. Almod (22° 23′ : 78° 26′) lies in the Satpura region at the south base of the Pachmarhi scarp. The beds consist of sandstones and carbonaceous shales and have been included in the Bijoris by Mr. H. Crookshank as a result of recent investigations.

Panchet series: Maitur and Hirapur stages and Mangli beds.

The Panchet series overlies the Raniganj series of the Raniganj coalfield, but is not included in the Damudas. Their basal beds contain plant remains of the Damuda flora near Maitur (23° 42′ : 86° 58′) and fragments of a vertebrate fauna (Dicynodont and Labyrinthodont) near Deoli (23° 39′ : 86° 53′). The Panchets contain no coal seams or even carbonaceous shales. The lower stage, including the Maitur and Deoli beds, consists in general of Talchir-like greenish-buff to yellowish-brown sediments (sandstones and clay-shales), and the upper stage around Hirapur is characterised

by yellow-grey, micaceous sandstones and red clays. The whole series is probably between 1,500 and 2,000 feet thick. No rocks of this series have been found in the Jharia field, but further up the Damodar valley and in the Palamau coalfield of Aurunga, there are strata above the Damudas which may be the equivalents of the Panchets.

The Almod beds of the Satpura region may be in part Panchets, or at least may bridge the gap between the Panchets and the Raniganj series. This, however, is merely an assumption for which the only justification is the fact that the Panchets are clearly closely related to the Damudas. The fish scales recently found by Mr. E. R. Gee in the Lower Panchets have been identified as belonging to the Palæoniscid genus *Amblypterus*, which is a Palæozoic form. This evidence, in addition to the presence of *Glossopteris*, *Schizoneura*, and other plant fossils in the Maitur exposure, gives the Panchets a strong Permian, or at least, a Permo-Triassic, aspect.

Elsewhere in the Indian Peninsula, the only strata which can with any certainty be regarded as possible representatives of the Panchets on definite fossil evidence are the Mangli beds of the Wardha valley area. Near the village of Mangli (20° 22′ : 79° 4′), the cranium of a Labyrinthodont reptile (*Brachyops laticeps*) was found by the Rev. S. Hislop[1] about 1854. Although Mr. T. W. H. Hughes considered these beds at Mangli as equivalent to the Kamthis on lithological grounds, Dr. W. T. Blanford was impressed by the fauna obtained (which included a species *Estheria* in abundance: a similar crustacean has also been found in the Panchets) and regarded the beds as the equivalents of the Panchets. This correlation is still maintained by the author and also represents the official opinion of the Geological Survey of India.

Upper Gondwanas: Mahadevas; Rajmahal; Jabalpurs and Umia beds.

It has previously (page 9) been stated that workable coal seams are rare in the Upper Gondwanas of the Peninsula, but that the Loi-an series in the Southern Shan States of Burma is more attractive in this respect; poor seams occur in the Jurassic strata of Cutch (near Bhuj; 23° 15′ : 69° 44′) in the Bombay Presidency and, across the Indus, in the Mianwali district (near Kalabagh; 32° 58′ : 71° 37′) of the Punjab. The most complete and, at the same time, best developed, succession of the Upper Gond-

[1] *Q. J. G. S.*, X, p. 470, (1854).

wanas occurs in the Satpura area around the Mahadeva or Pachmarhi hills. The strata are normally subdivided as below :—

Upper Gondwanas .	Jabalpur series .	Jabalpur stage.
		Kota stage.
	Mahadeva series .	Bagra beds.
		Denwa stage.
		Pachmarhi stage.

These subdivisions are not easily separated in the field as the strata are evidently not only a conformable series, but also pass laterally one into the other in the lower stages. They are all fresh-water sediments. The Pachmarhis are largely sandstones where typically developed, but also contain red clays, both at their base and at the top. The Denwas are characterised by the presence of red clays which are often interbedded with sandstones of the Pachmarhi type. Mr. H. Crookshank has found that these two stages of the Mahadevas merge into each other by the elimination of the typical facies of each. The Bagras consist largely of pebble beds and conglomerates characterised by the presence of red jasper. They were thought to be a lateral (shore-line) facies of the Denwas, but in some sections they appear to form the basal beds of the Jabalpur series. Obscure plant remains occur in the Denwas and it was in the Denwa river near Jhirpa (22° 36′ : 78° 31′) that Mr. T. W. H. Hughes (in 1877) picked up the scute of a Parasuchian crocodile (*Mastodonsaurus indicus*). It is the evidence of this fossil alone which has permitted the fixing of the age of the Denwas as Upper Trias (Rhaetic to Keuper).

As a result of the discovery plant fossils of Kota (Middle Jurassic) age in the lower beds, the Jabalpur series has been subdivided into an upper (Jabalpur) and a lower (Chaugan) stage. It would thus appear that the Jabalpur series and the Mahadevas represent a time interval from Middle Trias to Upper Jurassic. Coal has been found in the Jabalpur series in the Hard river (junction with Sakkar river, about 22° 45′ : 79° 5′) and also in the Moran river above Lohartalai (22° 22′ : 77° 30′). In neither case has the coal proved worth exploitation.

Although the Rajmahal series of the type area (Rajmahal hills) contains no coal and is quite 1,500 to 2,000 feet thick, only about 100 feet of these beds are of sedimentary origin. The remaining strata are basaltic lava flows. The plant beds constitute inter-

trappean sedimentary strata among the lower four or five flows. The fossil evidence from these beds has been accepted as indicating a Lower Jurassic (Liassic) age. They thus correspond with a horizon at the top of the Denwas and below the Jabalpur series. They correspond in position with the lowest (Golapilli) beds of the Jurassics of the East Coast, and possibly with the Loi-an series of Burma. They are, of course, lower in position than the Kota beds of the Wardha-Godavari valley. In this region, the Jabalpur series is further represented by the Chikiala sandstones, which are of interest in that a seam of coal occurs in them[1]; but it is not of economic value. The coal horizon in the Umia beds of Cutch is thought to be somewhat higher than the Jabalpur stage of the Satpura region and therefore to be of lowest Cretaceous age. The coal is not considered of any importance.

Beginning from the Madras coast on one side and the Cutch area on the other, these Upper Gondwana strata are associated with marine sediments, although they consist of fluviatile deposits within the limits of the Peninsula. The Loi-an series of Burma has recently been found to have similar marine beds below, near Legaung (20° 50′ : 96° 33′) north of Kalaw. And it is becoming more certain that the coal of Henzada near Kywezin (17° 58′ 30″ : 95° 9′) is also of Jurassic age and probably the equivalent of the Loi-an series. These coals of Henzada have attracted attention for many years, but have so far, owing to their crushed condition, not been opened to commercial export. The Jurassic coals of the Punjab near Kalabagh and Kuch (33° 1′ : 71° 35′) are too thin and irregular for development. They have, however, been worked on several occasions, but without success for any length of time and then they found only a local market.

Basaltic and Other Igneous Intrusions in the Gondwanas.

Almost every coalfield of the Gondwanas contains dykes and sills of dolerite and basalt. These basic rocks, however, have seldom done very much damage to the coal seams. They have rendered mining more expensive in some areas, where drivages have had to be made through the hard rock. In most cases, the doleritic material is of Deccan trap age. But there is some doubt

[1] *Rec. Geol. Surv. Ind.*, XI, p. 30, (1878).

whether the dolerite dykes, which are so common in the belt of country from the Satpura Gondwana basin through the South Rewa country into the Damodar valley, are all of the same age. There is no doubt that the intrusions of the Satpura and Rewah areas are of Deccan trap age. And this also seems to be true of the coalfields of Palamau, but it is possible that those of the Damodar valley are of Rajmahal age. There is no proof for this view. The dolerite dykes in Assam are, from their intrusion into the Lower Gondwanas of Singrimari in the Garo hills, assumed to be of Rajmahal age.

In the Damodar Valley coalfields and in the Giridih and the Darjeeling foothills, the coal measures are intruded by dykes and sills of ultra-basic rocks which are termed mica-peridotites. These intrusions are of about the same age as the dolerite (basaltic) dykes, but unlike the latter the peridotites have spoilt large quantities of good coal. These ultra-basic intrusions were evidently extremely fluid when injected and have traversed the bedding planes of the strata, especially in contact with or within the coal seams, and have 'coked' the coal into natural coke and otherwise rendered it useless or unprofitable to mine. It is very curious that the mica-peridotites appear to be confined to the Damodar valley and north-eastern region. It must also be stated that basaltic (dolerite) dykes are relatively rare in the coalfields south of the belt known as the Satpura protaxis. For example, dykes are practically unknown in the coalfields of the Mahanadi (Talcher, Ib river, etc.), of the Godavari (Singareni, etc.), and of the Wardha valley (Ballarpur, Ghugus, etc.).

Structural Features of the Gondwana Coalfields.

The curious distribution of the Gondwana coalfields in the Indian peninsula has been noticed on several occasions. It is the opinion of those who have given the matter careful attention that these Gondwana sediments were laid down in lakes in 'rift' valleys. There appears to have been a belt of trough-faulting along the line of the Narbada-Son, including the country some distance to the south. And there appear to have been branches from the main 'rift'—(A) into the Damodar valley; (B) down the Mahanadi; and (C) down the Wardha-Godavari. But the distribution of the coalfields is not quite confined to these simple limits. There is

evidence of the presence of Talchir and Barakar sediments in the intervening country—especially about Hazaribagh and Giridih.

Except for sharp dislocation by faulting and a certain degree of induration along fault-lines, or on lines of intrusion, the Gondwana sediments in the Peninsula are usually found gently inclined. Recent work in the Jharia and Raniganj coalfields and in the Satpura region has shown that this simplicity is not without exceptions. In the areas examined in the above coalfields, it has been found that overriding and overthrust movements have not been absent in these areas. And yet these are tracts well within the limits of the stable Peninsula. In the Eastern Himalaya, of course, it is well known that the strata are greatly folded. The Gondwanas of the Darjeeling area for example are upside down due to overfolding. However, whatever may be the tectonic disturbances to which the strata of the coal-bearing Gondwanas have been subject, faulting is perhaps the most evident.

Faults in the Coalfields.

In the Himalayan areas, it is quite evident that the overfolding and faults are due to the movements which have taken place in late Tertiary times. In the Damodar valley and other Peninsula coalfields, which are generally cut off along one or other boundary by great faults, it is not easy to arrive at the age of the dislocation. In the Satpura coalfields, it is quite certain that faulting has occurred *after* the Deccan trap erruptions, *i.e.*, since Upper Cretaceous times, and it is thus likely that the faults are of Tertiary age. It is, however, suspected that the main boundary faults are much older and probably kept step with the deposition of the Gondwana sediments. This is in conformity with the idea that the Gondwanas were largely laid down in regions of trough- or rift-faulting.

In the Damodar Valley coalfields, the evidence from the faults within the Gondwanas is that the faults are nearly all *older* than the trappean intrusions (both dolerites and mica-peridotites). If, therefore, these intrusives are of Jurassic age, the faults are certainly due to movements of an earlier epoch. It is consequently of interest that Mr. G. V. Hobson found evidence of faulting in the lavas and dykes of the Pachwara coalfield in the Rajmahal hills. It may thus be possible that the intrusions in the Jharia and other coalfields are truly of Deccan trap age, but even this probability does

not clear up the mystery regarding the absence of newer faulting in these fields. Dr. Jowitt's work in the Karanpura coalfield has shown the presence of two series of faults—one pre-Mahadeva and the other post-Mahadeva. As the Mahadevas are at least the equivalent of the Rajmahal series it is clear that the Damodar valley and Rajmahal areas have been subject to tectonic disturbances later than the early Jurassic epoch.

The majority of the faults are of the normal type. Most of the faults in the Satpura-Rewah-Damodar belt of coalfields have a prevailing E. N. E. to E. S. E. trend. In the Wardha-Godavari basin, the faults approach a more north-south direction. Cross faulting, sometimes of large throw, occurs in most coalfields. In the Jharia coalfield, many of the faults were found to belong to the 'tear or sag' type. They begin in small displacements, attain a throw of 200 or more feet, and then die out in a short distance on their line of strike!

CHAPTER 3.

DISTRIBUTION OF LOWER GONDWANA COALFIELDS.

General.

The coalfields under consideration are, of course, those of the Gondwana system and of the Damuda sub-system in particular. These Lower Gondwana coalfields and coal-bearing strata are found in restricted areas from the Eastern Himalayas to the Satpura uplands of the Central Provinces. They occur down the valleys of the Wardha and Godavari rivers, and from South Rewah into the drainage area of the Mahanadi in Orissa. They are best known in the Damodar valley and the intervening country into the Rajmahal hills. If the plant remains found in the Vihi district of Kashmir and in small exposures in the Punjab Salt Range are included, the area involved is still larger; but it must be stated that no coal has been found in these beds in the Punjab and Kashmir tracts.

In a previous memoir[1], I endeavoured to show the distribution of land in the Indian region during the Permian period when the Lower Gondwana strata were being deposited. Although the chart there published is open to considerable criticism, especially in regard to the shore-lines between Calcutta and the Himalayan area to the north, there are features which must be noted. The true coalfields are shown to lie in original fresh-water basins of restricted extent. These may briefly be termed (1) the Godavari-Wardha basin; (2) the Satpura basin; (3) the Mahanadi basin; (4) the Chhattisgarh-Rewah basin; (5) the Son-Palamau basin; (6) the Damodar basin; and (7) the Eastern Himalaya. In the eastern areas of the Himalaya, south of the axis of the range, the Damuda coal measures are associated with (overlie ?) marine beds also of Permian age. Here then is an indication of a shore along the northern coast of Gondwanaland.

The Upper Plateau limestone of the Shan States of Burma is probably represented by the Subansari blocks of fossiliferous

[1] *Mem. Geol. Surv. Ind.*, LVIII, p. 10, (1931).

limestone found in the Eastern Himalaya. And the fossiliferous limestones of the Moulmein and Tenasserim areas are, from their fossil evidence, believed to be of the same Permian to Upper Carboniferous age as the beds above mentioned. From these data and the plant remains (as coal) in the Tenasserim (Therabwin) area and the marine (brackish water) fossils from near Martaban (Salwin series) of slightly later (younger) age there is an indication of shore conditions in these areas of the Permian period. Finally, the marine fossils from (1) South Rewah (near Umaria), (2) from the Punjab Salt Range (near Warcha) and (3) from the Kashmir (Vihi district) area, which are in close association with plant fossils of a *Glossopteris* flora, also mark the vicinity of the coast of Gondwanaland in Permian times. We know nothing of the southern coasts of Gondwanaland, but it is the general opinion of all geologists that India was connected with South Africa during the Upper Palaeozoic and the Mesozoic periods.

There are thus some reliable data for the belief in a great southern continental area over Peninsular India in Permian times, with an extensive ocean round its northern coasts from the Punjab and Kashmir tracts to north-eastern Assam and southward to the limits of Burma. We do not know if the region of the Bay of Bengal was land at that epoch, but this is the view held both by Dr. L. L. Fermor and myself from different lines of study. The main drainage of the Gondwana continent in the Indian region appears to have been in a northward direction; at least the outlets of the Godavari and Mahanadi basins were towards the north into the western Satpura tract in the case of the former, and into the South Rewah area in the case of the latter. In both cases, the outlets were probably restricted as the deposits are thinner in these directions than they are in their respective basins to the south. It is not possible to say in what direction the Satpura basin discharged its waters, but the present belief is in a northward outlet. A land barrier appears to have been present between the Satpura and South Rewah basins. The latter area possibly connected with the sea northward, at least for a time, but there is some evidence to show that the Son valley Gondwana deposits were part of a drainage system which had an outlet eastwards in the direction of the Damodar coalfields. It is probable that the Damodar region formed part of a great deltaic tract which continued north-eastward. Dr. L. L. Fermor has suggested that another large drainage area also

discharged northward from the tract now covered by the Bay of Bengal—a view which is attractive and not improbable.

The position of the chief basins, in which the Lower Gondwana coal measures are found, appears to have been primarily due to the existence of a system of rift valleys converging to a great rift valley, roughly on the line of the present Narbada-Son-Brahmaputra valleys. These basins were, it may be suggested, maintained by isostatic adjustment as the deposits accumulated in each basin. Where the deposits are thickest the boundary faults are greatest, so that they are to some extent of the nature of 'sag' faults. The coal measures by being more deeply buried in these basins have thus escaped the erosion which has subsequently taken place. They have not been preserved in their entirety and their preservation in some areas has been due to the protecting cover of the Deccan lavas which overwhelmed the country at the close of the Cretaceous period. Erosion appears to have been greatest in the Damodar valley area and in the country to the north of it, where remain now only remnants of an extensive spread of original Gondwana sediments.

Assam, Burma and Bengal Coalfields.

The coalfields of Lower Burma can be dismissed briefly with the statement that, although crushed, graphitic coals have been met with in strata which overlie limestones with a marine Permian fauna, the extent and character of the coals gives little hope for the discovery of more extensive areas of coal measures, owing to the erosion which appears to have taken place since those deposits were laid down. The Permian age is a guess as the coal seams overlie the limestone. The coal measures may be of Triassic age and so related to the Salwin series[1], or distantly related to the Triassic coals of Yunnan.[2] There are younger and more attractive coal measures in Tenasserim but these are of Tertiary age and will be considered in a subsequent memoir.

In the Eastern Himalaya from north-east Assam along the southern margin of the hills westward into the Darjeeling district of Bengal and on to the Nepal foothills, about the confluence of

[1] *Mem. Geol. Surv. Ind.*, LVIII, p. 210, (1931).
[2] *Op. cit.*, XLVII, p. 65, (1923).

the Sun Kosi and Arun rivers, coal-bearing Damuda strata have been traced in an almost unbroken series of exposures. It is known, however, that the belt of Damudas is not continuously present owing to overthrust faulting and lateral dislocations; but the evidence is that these strata were part of a continuous deposit. As the seams are found severely crushed and overfolded and dip at steep angles northward into the hills, their exploitation is both difficult and expensive. The structure of the beds shows that the fold of which they form one limb must be resolved southward under the alluvium of the Brahmaputra and Ganges rivers. In the Assam area, granitic rocks are seen in the neighbourhood of the Brahmaputra near Gauhati and other places, so that if these coal measures were once present to the south they have since been removed by denudation except close under the hills. In the tracts south of Darjeeling, the alluvium is deep, while the presence of gneissic rocks near Colgong at the north-west corner of the Rajmahal hills shows that they are unlikely to occur in the direction of Patna. Nevertheless it is possible, as Mr. F. R. Mallet[1] has suggested, that coal-bearing Damudas may underlie the alluvium between the Darjeeling Himalaya and the Rajmahal hills.

In the Rajmahal hills, practically all the Lower Gondwana coal measures show up from below the basaltic lavas along the western flanks of the hills. The lavas and with them the underlying sedimentary series have a low easterly dip under the alluvium of the Ganges. It is not improbable that these Gondwanas of the Rajmahal hills extend southward beneath the covering rocks and alluvium to join the Gondwanas which similarly form the hidden eastern limits of the Raniganj coalfield. There are significant outlying patches of Damuda rocks near Suri in the tract between the southern part of the Rajmahal hills and the Raniganj coalfield. This and the existence of the coal measures of the Deogarh fields, of Giridih and elsewhere to the west in Hazaribagh, suggest a once widespread area of these Lower Gondwanas.

The fact that Lower Gondwana sediments have been found on the extreme western end of the Assam range in the Garo hills, at Singrimari (25° 44′ : 89° 54′), proves that such strata were probably deposited widely over north-western Assam and north-eastern Bengal. The oldest fossiliferous strata found in those hills are of Upper

[1] *Mem. Geol. Surv. Ind.*, XI, pp. 32-33, (1874).

Cretaceous age, so that there was ample time between the Damuda period and the close of the Mesozoic era for the removal of any Lower Gondwana coal measures. This supposition must, if true, carry with it the corollary that the Damudas under the Ganges-Brahmaputra alluvium eastward of the Rajmahal hills and the Raniganj coalfield also suffered considerable denudation during the same period of late Mesozoic time. These theoretical considerations, however, are not of much practical value as it will be very many years yet before the hidden eastern extension of the Raniganj coalfield will come under serious examination. Furthermore, there are now cogent reasons for believing that a line of faulting trends up the Brahmaputra side of the alluvium from the delta about Barisal N. N. W. into Cooch Behar towards the western border of Bhutan. The upthrow side of the fault is the Garo hills of Assam, so that the movements tend to drop the coal measures, if any, deeper under the alluvium.

Bihar Coalfields.

Rajmahal hills, Deoghur and Hazaribagh coalfields.

As already stated, Damuda coal measures show up at intervals from under the basaltic lavas along the western margin of the Rajmahal hills. The basal rocks of the region to the west are gneisses, etc., of Archaean age, which continue into the Hazaribagh plateau. In the intervening tract of country lie the outliers of Lower Gondwana rocks in the little coalfields of Deogarh, the larger field of Giridih, and the small fields of Chope and Itkhuri. In various places somewhat north of these scattered coalfields there are outliers of Talchir rocks. The whole region in fact appears to have been covered by a more or less continuous deposit of Lower Gondwana strata which has since been nearly completely removed by erosion. In every instance the Damuda outliers are found in association with faults, which have probably been the chief factor in their preservation. There is thus a possibility that all the outliers have not yet been discovered, but it is more or less certain that the discovery of an extensive coalfield, preserved by faulting and obscured by soil and alluvium, is most unlikely, as the area has been traversed although not minutely examined by various geologists.

Damodar Valley coalfields.

The chief coalfields of the Damodar valley are, from the east, the Raniganj, Jharia, Bokaro, Ramgarh, and North and South Karanpura fields. There is no doubt at all now that these disconnected coalfields were once part of a great spread of Gondwana strata. Whether this large original Gondwana basin connected northward with the outliers of the area discussed in the previous paragraph is not certain ; but it is very probable. In the Damodar valley coalfields, the presence of great boundary faults, chiefly along their southern margin explains fully how the Damuda strata have escaped denudation. In the case of the Raniganj coalfield, the southern boundary fault, at one point at least, must have a displacement of nearly 10,000 feet. The beds in these coalfields have a general dip to the south, *i.e.*, towards the main faults.

In addition to strata of Lower Gondwana age—Talchirs and Damudas—found in the Raniganj, Jharia, Bokaro and Karanpura coalfields, there are Panchet and Upper Gondwana strata in one or other of them. And it is considered almost certain that the younger beds were also once continuous over the Damodar valley and the country to the west, where similar beds are still to be found. In addition, my own observations, in these areas and the tracts to the south-west in Sirguja and to the north-west in the Mirzapur country, lead me to believe that the Deccan basalt lavas also covered the Upper Gondwanas in at least the higher parts of the region under consideration. These features at once indicate the vast amount of denudation which has occurred in this area.

During the re-survey of the Jharia coalfield, and since, there have been frequent rumours and reports of the finding of coal in the gneissic area south of the existing belt of the Damodar valley coalfields. Although none of these discoveries have so far been substantiated there is no theoretical reason why some small outliers should not occur. In this connection it is of considerable interest that in an old map by Captain Walter S. Sherwill, dated 1852, an outlier of Damuda rocks is shown about 12 miles W. N. W. of Chas (23° 38′ : 86° 10′). The exact locality is roughly west of the old semaphore tower and possibly in the Khanjo *nala* two miles north of the Inspection bungalow at Majhidih (23° 40′ : 86° 1′). The area is south of the eastern end—Dhori (Dori) Colliery—of the Bokaro coalfield and of course south of the Damodar river. Captain Sherwill's map has been tested in regard to other data

and found to be trustworthy. However, Dr. J. A. Dunn specially visited this tract in December, 1932, and traversed the Khanjo *nala* but found no trace of Gondwana rocks of any kind. All the exposures seen by him were the gneisses common to that area.

Palamau coalfields: Aurunga, Hutar and Daltonganj.

Continuing westward from the Damodar valley area, over the watershed into the drainage of the Son valley, there are three isolated areas of Gondwana strata, in each of which workable coal of the Damuda sub-system occurs. The distribution of these coalfields is such that it seems obvious that they are remnants of a much larger spread of Gondwana strata, and indeed were probably the westward extension of the Gondwanas of the Damodar valley. Of the three Palamau coalfields in the area under consideration, two are directly on the line which joins all the Damodar Valley fields, while the third (Daltonganj) is north of this axial line. This northern field has evidently been subject to far more denudation, as only the Talchir and Barakar (Karharbari) series are present.

The Aurunga and Hutar coalfields have small outliers of Upper Gondwanas in them. The most curious feature, however, is that whereas the Raniganj and Panchet series have been recognised in the Aurunga (east) field between the Barakars and so-called Mahadevas, the Mahadevas lie directly on the Barakars in the Hutar (west) field. And this hiatus appears to be present in the western part of the Aurunga field, *i.e.*, the end nearest the Hutar field. Dr. Dunn, who has recently re-surveyed both these fields, says that the Mahadevas appear to overlie the Barakars of the Hutar area conformably. He also states that no fossils have been found in the Mahadevas of either field. A fossil locality near Pandepur (23° 46′ : 84° 32′) in the Aurunga field, thought by Dr. Ball to be in the Mahadevas[1] is shown by Dr. Dunn to be in the Panchets.

If the Mahadevas of these fields are truly Upper Gondwanas it is evident that a considerable amount of denudation or a long period of non-deposition elapsed subsequent to the Panchet epoch. Dr. Dunn has also noted a slight discordance between the Talchirs and the Barakars, although he suggests the Barakars may include the Karharbari stage. This lower hiatus has been noted in all the Damodar Valley coalfields and elsewhere in India. The separation

[1] *Mem. Geol. Surv. Ind.*, XV, pp. 39-40, (1878).

of the Raniganj and Panchet series from each other in the Aurunga coalfield is also recognisable in the Karanpura coalfield as well as in the Bokaro field. The non-recognition of the so-called Ironstone Shales (Barren Measures) is also of interest in the Aurunga area where the Barakars are overlain directly by the Mahadevas. It is evident that in addition to the possibility of considerable erosion of the Lower Gondwanas, there is also an indication that the Damudas were originally thinner towards the west than is the case in the Raniganj coalfield.

Orissa Coalfields.

As in the case of the Damodar Valley coalfields, so also up the valley of the Mahanadi and Brahmini rivers there appears to have been a continuous spread of Lower Gondwana strata in a W. N. W. direction from the coast near Cuttack into the region of Chhattisgarh. At the present time, a patch of Upper Gondwanas (Rajmahals) occurs about Athgarh near Cuttack, while a coalfield (of Damuda strata on Talchirs) lies further west in the Angul tract. Although this spread of Gondwanas is separated from the next to the west in the Sambalpur district it is certain that both were at one time connected. Here, again, there is evidence of erosion or non-deposition of the Upper Damudas as no beds of the Raniganj and Panchet series appear to be present. The Mahadevas at the western end of the Talcher coalfield are represented as lying directly on the Talchirs. It is, however, known that the equivalents of the Raniganj and Panchets occur in the large area of Gondwana rocks which extend westward from the Ib River coalfield into the coalfields of Hingir and the Hasdu in Chhattisgarh.

Talcher and Ib River areas.

Central India Coalfields.

The coalfields of Palamau are now regarded as outlying evidences of the great area of Gondwana rocks which extends westwards and southwards up the Son valley into South Rewah. Much of this region, which also extends into the northern tracts of Chhattisgarh, is covered by Upper Gondwana (? Mahadeva) rocks. But from below this cover there are several areas in which Lower Gondwana rocks show.

Son valley in Rewah.

Among the more important of these, ones in which coal-bearing Barakars appear, are the coalfields of Singrauli, Umaria, Korar, Johilla river and Sohagpur. And it is thought that the coal measures extend under the younger Gondwanas of the region. These younger rocks include representatives of the Raniganj series and Upper Gondwanas, but no borings have been put down through the younger rocks to prove the extension of the coal measures under them. In all the South Rewah coalfields mentioned above the Talchirs are found below the coal-bearing Barakars.

It will be remembered that in a small exposure near Umaria marine fossils have been found in beds which are evidently at the base of the Barakars, and which overlie the Talchirs with a slight unconformity. The South Rewah tract of Gondwanas forms the western and north-western continuation of the Gondwanas from the Damodar valley and the Mahanadi basins. In the fork lie the coalfields of the Chhattisgarh region next to be discussed. To the west lies the watershed between the Son and Narbada rivers in country entirely occupied by Deccan trap lavas. Nevertheless, the examination of the South Rewah coalfields has shown that the Upper Gondwanas evidently overlap the Lower Gondwanas on to the gneisses and other Archaean rocks, before they themselves thin out in the same way and become covered by the Deccan trap flows.

Central Provinces Coalfields.

The Chhattisgarh coalfields.

The coalfields of Chhattisgarh (which includes the Feudatory States of Chang Bhakar, Korea, Sirguja and Udaipur) and the Bilaspur and Raigarh districts may be divided as a whole into a northern and a southern group. In Damuda times, there appears to have been between them a watershed or belt of higher ground. This followed an east to west line through the Main Pat of Sirguja into the adjacent tracts of Jashpur to the east and towards Amarkantak to the west. As a result of this ancient ridge, no Damudas occur on the line of the ridge, which is largely composed of pre-Gondwana rocks with patches of Talchirs overlapped by younger Gondwana strata and newer rocks (basaltic lavas).

Among the northern coalfields of Chhattisgarh are those of Tatapani, Ramkola, Jhilmili, Korea and Sirguja (Bisrampur). The Sir-

guja (Bisrampur) field, and Bansar, are outliers south of the several fields above named. Forming a link with the northern fields are those of Lakhanpur (with Bansar, Panchbhaini, Sendurgar, Damhamunda) and Rampur in Sirguja. These might be part of a narrow connecting valley between the northern basin and that to the south through the supposed ridge of the Damuda epoch. The coalfields to the south also emerge from beneath younger Gondwana strata. Among these are the areas referred to as the Korba, Mand River, and Raigarh fields. The same spread of Gondwanas extends south-eastward through Hingir to the Ib River coalfield, originally called the Rampur coalfield. From the fossil evidence from Garjan Hill in the Hingir area[1], the overlying beds between the Mand River field and the Ib River field are now considered to be representatives of the Upper Damudas.

Narbada valley and Satpura basin.

Thin seams of coal of Upper Gondwana (Jabalpur) age have been found and in places worked along the southern margin of the Narbada valley and the adjoining tract of the Satpura hills. The better known localities are at Jabalpur (in a well); Lameta Ghat, nine miles to the south-west; on the Mahanadi north-east of Jabalpur; at Sehora on the Sher river and near Murpipria; the junction of the Hard and Sakkur rivers; on Nimuagarh Hill near Mohpani; below the Khatama caves, of the Zumani glen; and in the Moran river above Lokartalai. All these outcrops or proved occurrences are of no economic value and as stated they are all in rocks of the Upper Gondwana (Jabalpur) age.

Among the exposures of Lower Gondwana (Damuda) coal measures in the Narbada valley tract and the hills bordering it to the south, are those of Mohpani and Gotitoria at the debouch of the Sitarewa river, and again further west in the lower reaches of the Tawa and Denwa rivers a little above their confluence, and round from Kesla, at intervals, to the Sonbhadra eastward to the Denwa valley south of Delakhari. The exposures on the line eastward from Kesla are of little value and are now proved to belong to strata of Raniganj (Bijori) age. The exposures of the lower Tawa and Denwa have not proved attractive, and it is not certain whether they represent Raniganj or Barakar beds. There is no

[1] *Rec. Geol. Surv. India*, VIII, p. 115, (1875).

doubt about the Barakar age of the coal measures of Mohpani and Gotitoria.

The Satpura basin, which strictly includes all the country bordering the Narbada plains from south of Jabalpur to beyond Lokartalai and the hilly region to the south, contains a great area of Gondwana rocks. There are evidences in support of the view that the Gondwanas lie in a belt of trough-faulting, and that the Lower Gondwanas at all events were deposited in a 'rift' valley, more or less coincident with the present belt of these rocks. But the overlying Upper Gondwanas and upper strata of the Damudas almost entirely conceal the coal measures and Talchirs. These older rocks show up at intervals in small areas along the northern margin of the Satpuras at Mohpani (the Sitarewa), near Fatehpur (the Anjan and Pathapani confluence), mile 8 on the Piparia-Pachmarhi road, and one or two other places.

The structural features suggest that these Talchir and coal measures (Barakars) of the northern margin of the Satpura region have been brought to their present position by faulting, and that to the south these strata occur at some considerable depth in the synclinal under younger strata chiefly of Upper Gondwana age. Along the southern margin of the Gondwana tract in the Pench and Upper Tawa valleys, there is an almost continuous outcrop of Talchirs and Barakar coal measures from the longitude of Sirgora (79° E.) to beyond Sonada (77° 50′ E.), where these beds pass under younger rocks and the Deccan trap. It is also seen that the beds have steady northward dips under younger beds of the Damudas. Traverses northward also show, except for slight reversals, that the northward dips are continued in the overlying beds, including those of the Mahadevas (Upper Gondwanas), almost to the northern margin, where the Talchirs and Barakar coal measures already referred to emerge.

It will thus appear that the Satpura basin must contain a great coalfield in which the coal measures as a whole lie at unworkable depths. The evidence so far obtained lends support to the view that to the east the Barakars (and perhaps the Damudas as a whole) die out under the trap flows of Seoni. A similar phenomenon has been observed in South Rewah. If this is correct it means that in Damuda times a ridge, probably trending north and south, separated the Satpura from the South Rewah Gondwana basin. The facts lend support to the opinion that the Lower Gondwanas were always

absent in this intervening region (of Seoni and Mandla). In the Satpuras our knowledge of the extension of Barakar (coal) measures westward is equally uncertain.

Gondwana rocks have been recognised beneath the Deccan traps at the foot of the Gawilgarh hills (scarp), in Ellichpur (Berar), in the intervening country and near Nagpur. In these areas it would appear that the coal measures are missing. Near Nagpur the Talchirs are clearly present, while at Bazargaon and Silewada in the same district the strata have been proved by fossil evidence to be Upper Damudas (the so-called Kamthis). We do not know what the sandstones near Ellichpur are in the Gondwana succession, but it is thought that they are possibly Kamthis. The nearest coalfield of the Damuda (Barakars) measures is that of Bandar near Chimur (20° 31′ : 79° 25′) less than 50 miles south of Nagpur and appearing from below a cover of Deccan trap lavas.

The Wardha-Godavari coalfields.

About 24 miles south-west of the Bandar coalfield, where Kamthis also overlie the Barakars, coal measures again show up under Lower Gondwana (Mangli beds) rocks in the Lalghat *nala* near Dongargaon and roughly six miles north of Warora (20° 14′ : 79° 2′). And there is another small exposure of these rocks in the Wardha valley near Dehwal, which lies 6½ miles westward of Warora. Vindhyan rocks show up in association with these outcrops and a great spread of Deccan trap lies to the north of them. However, from near Warora in a belt 24 miles wide, there is a strip of Gondwana rocks trending south-east down the Wardha valley towards the Nizam's dominions of Hyderabad.

The belt of country outlined above has all the characteristics of an ancient 'rift' valley, as both to the east and west of it there are much older rocks with few outcrops of Gondwanas outside the limits indicated, and occasional inliers of these older rocks within it. There is a large area of Talchirs west of Chanda town. It would thus seem that if a search for coal is ever to be made to the northward under the traps it must be restricted to the extension of the belt already specified. It is in the southward extension of the belt of Lower Gondwana rocks that the coalfields of the Wardha and Godavari valleys occur. The better known areas in which Barakar coal measures have been found in the tract under consideration are those of Warora, Wun, Chargaon, Ghugus to near the Penganga, Chanda to Ballarpur and Sasti, Antargaon where

the belt is narrow, Aksapur, Tandur, Chinur, Bundella, Kamaram, Alapalli, Singareni and Kunigiri—all, after Sasti, being in the Nizam's dominions and largely in the Godavari valley—onwards into the Madras fields of Lingalla, Damercherla and Beddadanol in the Godavari valley above Rajamundry.

Throughout the tract in which these coal measures of the Wardha and Godavari valleys occur in small outcrops, there is a cover of younger (Kamthi) Gondwanas, so that an extension of the Barakars under them is normally to be expected. Attempts have been made in places to prove the coal measures, but it has so far been found more profitable to restrict mining operations to the actual exposures of the Barakars themselves. In most of the mines it has been found that the coal measures lie with gentle dips, that igneous intrusions are absent, but that the Kamthi strata are rather heavily water-bearing. Faulting is of course evident, but nevertheless there is little difficulty in working where the seams are attractively thick or of good quality coal.

Coal in South India and Madras.

The Barakar outcrops in the Godavari valley in the Madras territories are unfortunate in that the strata dip away from the border, and the main coal areas therefore lie outside the Province. There have been many 'discoveries' of coal in the Madras area other than those of the Godavari tract. Among these may be mentioned the borings put down west of Madras in Upper Gondwana rocks in the Chingleput and North Arcot districts. No coal was found and it is doubtful whether Lower Gondwana rocks occur below. It is not necessary to draw attention to the 'discoveries' in the Bellary, Nellore, Cuddapah and, most classical of all, Kistna districts, where subsequent search has failed to discover even the cause of the original 'find'. About the time of these *discoveries* of coal in Archaean and gneissic rocks in Madras, one was also reported from Mysore. A similar attempt to find coal in the gneisses of Mysore was made a short time ago in spite of the remonstrance of the Mysore Geological Department.

Extent of Lower Gondwana Coal Measures.

In 1873 Mr. T. W. H. Hughes[1] made an interesting set of measurements to show that the area under which coal probably occurs

[1] *Rec. Geol. Surv. Ind.*, VI, pp. 64-66, (1867).

Amounts within workable depths.

in India is of the order of 35,000 square miles and thus fifth in magnitude in the world sequence and three times as large as the figure estimated for Great Britain. Mr. Hughes gives the following table which has frequently been quoted since:—

Name of area.	Square miles.
Godavari area (including its affluents)	11,000
Son	8,000
Sirguja and Gangpur area	4,500
Narbada area (including its affluents)	3,000
Damuda	2,000
Rajmahal area	300
Assam	3,000
Unsurveyed and uncomputed areas	2,700
TOTAL	35,000

These calculations are, of course, largely of academic interest, because they cannot take into consideration some very critical factors. On the one hand, no data are given for workable depths to the coal and, on the other, the full extent of the area covered by the coal measures is not absolutely known even now. To take the latter first, it should be evident from what has already been stated in this chapter that although the Damuda coal measures probably covered ten or more times the area now occupied by these rocks, their richness in workable coal seams was not uniform, and in the former, the accessible coal measures are a only fraction of the area actually estimated by Mr. Hughes. In the Raniganj coalfield, the Barakar seams will probably never be accessible over a greater area than, say, one-fourth of the area of the visible spread of Lower Gondwana rocks, and in the same field, the Raniganj coal seams can hardly be worked under half the total area occupied by the coalfield. In the Aurunga coalfield, according to the opinions expressed by Dr. Dunn in connection with the quality of the coal found there, it is doubtful if any of the coal seams are worth exploitation. In the Satpura-Narbada tract, I can say that of the total area of 3,000 square miles estimated by Mr. Hughes, coal will be obtainable from about one-tenth of this area, and then only with considerable difficulty for most of this small extent.

These remarks are not intended to show that the Indian coalfields are of less value and less real extent than was stated in the

detailed reports of each coalfield, but simply to point out that the working of these coalfields must be conducted with as great efficiency as possible as regards extraction from the workable seams. In many areas the workable coal seams are few ; in others the seams are so thick that the methods of extraction make it necessary to leave large amounts of coal for the support of the roof ; and in yet other fields large areas of the good seams have been rendered unusable by intrusions of igneous rocks. It is thus seen that, though the existing spread of the Lower Gondwana rocks may be large, the extent of measures containing workable coal even to a depth of 2,000 feet is limited ; and of this fraction the coal that might be exploitable is subject to further drawbacks diminishing still further the quantities likely to be won.

CHAPTER 4.

COALFIELDS OF THE INDIAN BORDERLAND AND THE EASTERN HIMALAYA IN ASSAM AND BENGAL.

THE INDIAN BORDERLAND.

A piecing-together of the data on the distribution of land and sea over the Indian region in Upper Palaeozoic times gives us evidence for a belief in an icebound southern continent (Gondwanaland) with open seas to the north, north-east and east. At the time the Barakar coal measures were being laid down, *i.e.*, after the glacial conditions had largely passed away, a sea covered the western Salt Range extending into Afghanistan on the one hand and Kashmir on the other. Two horizons of Lower Gondwana plant remains have been found in the Punjab Salt Range—one at the base of the Speckled Sandstone by Mr. E. R. Gee (1932) and the other about 150 feet above the base of the Productus Limestone by Dr. G. de P. Cotter and others. In Kashmir the Gangamopteris beds have been known for some time, but neither in the Punjab, nor in Afghanistan nor in Kashmir, nor yet in Spiti, have any coal seams been found in these Upper Palaeozoic marine strata. The view was once held that the coal seams found in Western Afghanistan were the equivalents of the Lower Gondwanas[1], but the fossils collected by Sir Henry Hayden[2] have shown conclusively that the Saighan series of Eastern Afghanistan (similar to the beds from Western Afghanistan) is of Jurassic age.

Although we have little detailed information of the Gondwana or equivalent formations in Tibet, it can be said that the rumours of coal in the Nyang Chu valley, near Penang, and at Lhasa have been shown by Sir Henry Hayden[3] to be without foundation. The northward extension of the Damudas of the Eastern Himalaya into south-eastern Tibet is still an open question, but it is thought that the presence of the Subansiri beds[4] in the Abor country indicates the northern coastline of Gondwanaland. At all events there

[1] *Rec. Geol. Surv. Ind.*, XIX, p. 245, (1886).
[2] *Mem. Geol. Surv. Ind.*, XXXIX, p. 30, (1911).
[3] *Op. cit.*, XXXVI, p. 64, (1907).
[4] *Op. cit.*, LVIII, p. 215, (1931).

are no Lower Gondwana coal measures in Upper Burma as this region contains evidences of sea during that period.[1] And this is supported by the fact that although Triassic coals (unknown in India) occur in Yunnan[2], no Permian coals have been found in the western tracts of that part of China. It is only when we arrive in Lower Burma in Tenasserim that coal of Upper Palaeozoic age appears to be present. And even here it is not absolutely established that the unworkable occurrences of coal found in the strata which overlie the Moulmein limestones near Therabwin[3] are the same age as the limestones. These limestones are considered on fossil evidence to be of Permian (Anthracolithic) age, *i.e.*, the same as the Upper Plateau Limestones of Burma.

THE EASTERN HIMALAYA IN ASSAM AND BENGAL.

The first recorded discovery of Gondwana coal-measure strata—Damudas—in the Himalayan region is that of Sir Joseph Hooker.[4] This famous botanist, when visiting Sikhim in 1849, found poorly preserved plant fossils near Pankabari (26° 50′ : 82° 24′). This locality is situated at the foot of the spur that leads up to Kurseong, in the Darjeeling district. Among the fossils found by him were impressions of *Glossopteris* leaves, *Vertebraria* stems, and *Schizoneura* leaves and stalks. Owing to the state of preservation, no specific identifications were possible, but it was quite clear that the *Glossopteris* flora of the Lower Gondwanas was present.

Subsequent explorations by F. R. Mallet[5] in the Darjeeling district, H. H. Godwin Austen[6] in the Daphla hills, T. D. La Touche[7] in the Aka hills, P. N. Bose[8] in the Western Duars and Darjeeling district, J. M. Maclaren[9] in the Mishmi country of north-eastern Assam, G. E. Pilgrim[10] in the Bhutan foothills, J. Coggin Brown[11] in the Abor hills, by myself in the Pankabari to Teesta strip of the Darjeeling area, and recently by T. Sutton Bowman

[1] *Mem. Geol. Surv. Ind.*, XXXIX, p. 347, (1913).
[2] *Op. cit.*, XLVII, p. 63, (1920).
[3] *Rec. Geol. Surv. Ind.*, XXVI, pp. 97 and 151, (1893).
[4] Himalayan Journals, Vol. I, p. 402, (1854).
[5] *Mem. Geol. Surv. Ind.*, XI, (1874).
[6] *Jour. As. Soc. Bengal*, XLIV, Pt. 2, p. 35, (1875).
[7] *Rec. Geol. Surv. Ind.*, XVIII, p. 123, (1885).
[8] *Op. cit.*, XXIII, p. 237, (1890).
[9] *Op. cit.*, XXXI, p. 190, (1904).
[10] *Op. cit.*, XXXIV, pp. 31-36, (1906).
[11] *Op. cit.* XLII, pp. 239 and 252, (1912).

in the Nepal foothills, indicate that a belt of Lower Gondwana strata is traceable from the Arun river in Nepal to the Brahmaputra river near Sadiya (about Nizamghat; 28° 17′ : 95° 44′).

The geological surveys above referred to show that, not only are the coal seams so severely crushed and dislocated as to be in most cases unattractive to work, but that the strata are inverted, and only the overfolded limb of the beds has so far been met with. The dips are steep and northward, and mica-peridotite intrusions occur in the seams of the Darjeeling district. The fossil evidence has given rise to the impression that the coal measures belong to the Raniganj series, but this is by no means definitely established. From my own observations near Tindharia (26° 51′ : 88° 23′), where the width of the outcrop is over two miles and a conglomerate horizon occurs at the base (above the railway station), I was inclined to regard the strata as probably Barakars.

Beyond the Brahmaputra.

There is no record of the actual discovery of coal of Gondwana age beyond the Brahmaputra river in the Mishmi country. J. M. Maclaren [1] wrote that :—

> 'Beyond Nizamghat at the gorge of the Dibong river, a spot was pointed out by my Chulikotta Mishmi guide who affirmed that by day a cloud of black smoke and by night flames arose from the ground at that place. From his entirely circumstantial account, and from his care in indicating the exact spot on the slope of the opposite range, it seems at least probable that he was referring to a burning coal seam, such as has altered to coke much of the outcrop coal at Margherita. Fragments of coal have been picked up in the Dibong, but no importance need be attached to the fact....'

Dr. Coggin Brown [2] records that he was

> 'informed by Capt. O'Neil, I.M.S., that coal seams outcrop in the Aieng country east of the Dihong'.

It may be mentioned in passing that the Dibong of Mr. Maclaren's account is spelt Dibang in the Atlas of the Imperial Gazetteer of India (1909), and that the Dihong, which is the Brahmaputra at its debouch, is spelt Dihang in the same publication. Between these two south-flowing rivers is a strip of country traversed by a third south-flowing stream called the Sesiri.

[1] *Supra*, p. 190.
[2] *Supra*, p. 252.

Abor Hills.

J. Coggin Brown [1] discussing the Gondwana strata in the Abor hills above Janamukh in the Sirpo valley and from the Sireng stream near Rotung (27° 9′ : 95° 11′), states :—

'By far the greater part of the route crosses typical rocks of the Abor Volcanic series, but near the point where the Kalek-Mishing road crosses the Sireng, sandstones and shales of the Gondwana beds themselves were found....'

The coal associated with these disturbed measures occurs in lenticular patches up to four or five feet in thickness. Such exposures in difficult and hostile country may be considered as of no economic value at present. However, a feature of more than usual interest is the rare occurrence of rolled limestone boulders in the upper course of the river Sireng below Torne mountain (6,122 feet).

'These rocks undoubtedly belong to the base of the Gondwana series and must occur somewhere in the steep, jungle-covered ravine slopes of the upper Sireng.'

Miri Hills.

In 1846 coal was discovered by Lieutenant Dalton [2] on the Durjnu river at a point north of Dibrugarh (27° 29′ : 94° 56′) in thin seams three to eight inches thick with south dips. This report, and that by Captain Vetch [3] in the same year, of coal in the Dakaru stream, six or seven miles above its confluence with the Buri Suti, together with the rumour of coal in the Sisi river, do not evidently indicate Gondwana coals. Thin irregular bands of lignite or lenticles of bright coal are not uncommon in the Siwalik (Pliocene to Miocene) deposits along the foothills of the Himalaya throughout their extent from Assam to the Punjab. On the other hand the fragments of coal found in the Sundri and Subansiri rivers by Lieutenant Dalton and subsequently also by Mr. Maclaren may have been derived from Gondwana exposures. Mr. Maclaren states :—

'From the neighbourhood of the Subansiri pieces of coal were shown to the writer. The finders had an exaggerated idea of the value of their discovery, and refused to disclose the position of the main mass, further than saying that it came

[1] *Ibid.*, p. 239.
[2] *Cal. Jour. Nat. Hist.*, VII, p. 213, (1846).
[3] *Loc. cit.*, p. 368.

from the hills some considerable distance away .... some two or three miles east of Dhol' (? 27° 35′ : 94° 15′).

Daphla Hills.

Colonel H. H. Godwin Austen [1] found Damuda coal measures with almost vertical dips and on a north-east to south-west strike in the Dikrang river below Shikhi [2] (27° 12′ : 93° 42′). The seams found were from five to six feet thick and much crushed and splintered. He wrote :—

'It was most interesting to come on these rocks in this position, as they are no doubt the representatives of the Damuda series lately examined by F. R. Mallet and J. D. Hooker near Pankarbari. The coal has exactly the flaky structure described by Mallet.'

Aka Hills.

When accompanying the Aka Expedition from Tezpur up the Boroli river in 1883-84, Mr. T. D. LaTouche found in succession—drift (alluvium), Tertiary, Damuda and Daling rocks, in the hills. The Boroli is also spelt Borholi and as Bhareli in the Atlas of the Imperial Gazetteer (1909). A railway now connects Tezpur (26° 35′ : 92° 48′) with Balipara, 15 miles to the north, and about 25 miles from the locality (27° 8′ : 92° 45′) where the coal is said to have been found. The thickest seam noted was only 18 inches thick and of the prospects Mr. LaTouche wrote :—

'Even if the seams were thick enough to be worked, and not broken up and crushed as they are, their distance from the plains and the difficulties of transport would prevent their being worked at a profit, especially as there are much larger fields in Assam, and more easy of access, which have never been touched yet. Even in the Teesta valley, where these Damuda beds contain thicker seams of coal close to a line of railway, the attempts to work them have so far resulted in failure, principally owing to the crushed condition in which the coal occurs.'

Bhutan Foothills.

Our information in regard to the Bhutan Himalayas was largely obtained by G. E. Pilgrim [3] over 25 years ago. He noted several occurrences of coal in association with crushed Gondwana strata. In one case he found coal exposed by a landslip, in a tributary of

[1] *Supra*, p. 37.
[2] *Jour. As. Soc. Bengal*, XLIV, Pt. 2, p. 37, (1875).
[3] *Rec. Geol. Surv. Ind.*, XXXIV, pp. 31-36, (1906).

the Kalapani (Demakoosam) about two miles above where this stream leaves the hills (26° 55′ : 91° 55′). The Kalapani is itself a tributary of the Nanai (Nunai), which joins the Jai Bor or Bornadi and then discharges into the Brahmaputra almost opposite Gauhati (26° 11′ : 91° 51′). Coal was also found within the hills in the Bor or Bornadi about 12 miles west of the Kalapani locality. The nature of the material from these two exposures is shown by the following proximate analyses.

	Kalapani.	Bornadi.
	Per cent.	Per cent.
Moisture	1·82	1·28
Volatile matter	19·06	20·78
Fixed carbon	54·87	38·62
Ash	24·28	39·32
Colour of ash	pale grey.	pale grey.
Caking property	cakes strongly.	cakes strongly.

Damuda strata have been noted in two places near Dewangir (26° 53′ : 91° 30′) with crushed seams of coal in association. Further exposures occur to the west in the Manas river south of Sufali (26° 52′ ; 90° 59′). Railway facilities are available some 20 miles from these coal occurrences, but the character of the coal, its crushed condition, and its transport to the open country would hardly be worth the trouble.

Baxa Duars.

Lignite has long been known to occur near Santrabari and Jaintia (26° 42′ : 89° 36′) in the Baxa Duars on the borders of Bhutan. Attention was called to this occurrence by H. H. Godwin-Austen [1] as far back as 1865 and it was revisited 30 years later by H. H. Hayden [2] and shown by him to be due to lignified logs of wood in the Siwalik (Tertiary) sandstones. No Gondwana rocks have been found in that neighbourhood, and the strip of these rocks shown there on the new geological map of India is evidently due to a draftsman's error.

The general strike of the Damuda rocks seen in the Bhutan hills is somewhat south of west and would normally carry the belt of these strata into the Goalpara district and to about latitude 26°

[1] *Jour. As. Soc. Bengal*, XXXIV, Pt. 2, p. 106, (1865).
[2] *Rec. Geol. Surv. Ind.*, XXX, p. 249, (1897).

48′ in the Champatnati river. However, these rocks are not seen, and, in the Gadadhar (Sankos or Muchu) river, on the continued strike, Tertiary rocks are found against the Dalings (Buxa series) in latitude 26° 43′. In fact no Damuda strata have been found in this tract as far west as the borders of Bhutan (the Jalduha or Jaldoka river), while alluvium also covers the Tertiary rocks from about the Torsa river westwards. Damuda rocks are next met with beyond the De Chu (Jalduha) river in 27° 1′ : 88° 55′ on the borders of Sikhim. This position is roughly 25 miles north of where the Damudas might have been expected from the strikes observed in the Bhutan hills.

Great N.N.W.-S.S.E. fault.

From the behaviour of the Gondwana outcrops in the Eastern Himalaya between the Brahmaputra river and the Bhutan hills, and the re-appearance of these beds further west, it must be supposed that they are hidden and not absent in the tract between longitude 91° and 89° (*i.e.* between the Manas and De Chu rivers). However, the lateral displacement of 25 miles seems too large to represent a simple curve in the strike of the beds. The accumulating evidence during recent years points to a great line or zone of shear faulting, of considerable horizontal movement, along a line trending from the eastern border of Sikhim in the vicinity of the De Chu (Jaldhuna) river S. S. E. towards Rangpur and the Jamuna channel, west of the Madhupur Jungle, to the deltaic area near Barisal. Such a line of faulting would readily explain the small Lower Gondwana exposure at the western end of the Garo hills, the uplift of the Shillong plateau, the southward outlet of the Brahmaputra river, the phenomena of the older alluvium of the Madhupur Jungle and, most important of all, the earthquakes which are so destructive along parts of and in the areas adjacent to this line.

Darjeeling District.

The geology of this area along the foothills has been dealt with by F. R. Mallet [1] and by P. N. Bose. [2] Except for a small break in the continuity, Mr. Mallet had traced the Gondwana strata from below Sipchu on the Bhutan border (De Chu or Jaldhuha river) to the Balason river west of Pankabari (26° 50′ : 88° 20′). The

[1] *Mem. Geol. Surv. Ind.*, XI, (1874), and *Rec. Geol. Surv. Ind.*, X, p. 143, (1877).
[2] *Rec. Geol. Surv. Ind.*, XXIII, p. 237, (1890), and XXIV, p. 212, (1891).

strike in general is west by south to east by north, *i.e.* similar to that noted in the Bhutan and more eastern areas. This supports the fault theory of a big horizontal displacement in longitude 89°, if the strata are continuous under the alluvium of the Duars.

Mallet drew attention to the northward dips of the strata—from 40° to vertical—in the area along the Darjeeling foothills. The coal measures are inverted, but as no bore holes have been put down in the alluvial tract to the south, it is not possible to say whether the southern limb of the overfold occurs at a shallow or at a great depth. The opinion is that the coal measures are present but at a depth too great to be worked. In this connection, reference will be made later regarding Mallet's opinion of the southward extension of the Gondwanas under the alluvium.

It is also necessary to point out that lenticles of bright coal from the stems of trees occasionally occur in the Tertiary—Siwalik—strata, which occur as an outer fringe to the hills. Specimens of this material have often in the past been confused with the Gondwana coals. Analyses of this bright coal of the Siwalik strata are given below:—

Analyses of Siwalik coal from the Darjeeling district by H. Piddington.[1]

—	Sivok *nadi*, three miles above Teesta river.	Mahanadi valley.	Teesta river, west of the Chawa *nadi*.
	Per cent.	Per cent.	Per cent.
Moisture	6·80	5·50	10·00
Volatile matter	29·20	33·60	30·50
Fixed carbon	61·10	56·40	54·74
Ash	2·90	4·20	4·75
Specific gravity	1·32	1·32	1·30

The low ash-content suggests that this material probably represents lignitic tree stems, while the high volatile matter will presently be seen to distinguish this coal from the true Damuda coal found in the same areas.

Several seams of the Damuda coals can be studied on the road down from Tindharia (26° 51′ : 88° 23′). The best seam of coal found by Mr. Mallet in this vicinity is that below the railway work-

[1] *Jour. As. Soc. Bengal*, XXII, p. 313; *op. cit.*, XXIII, pp. 381 and 403, (1854).

shops. It is 11 feet thick. A drivage was made into it and coking tests and briquettes were made with the flaky material. The opinion then expressed was that it would be so expensive to work as to justify coal being brought from the Raniganj coalfield. And to this day the fuel used in the locomotives of the Darjeeling Himalayan Railway and in the tea estates of the area is brought from the Raniganj and Jharia coalfields. Mr. Mallet wrote of the coal in this tract in general as follows:—

'.. the crushing to which the seams have been subjected, has squeezed them so that they vary greatly in thickness within a few yards, and has induced a flaky structure in the coal which renders it so friable that it can be crumbled into powder between the fingers with the greatest ease.... The amount of metamorphism in the Damudas is by no means constant: generally the beds are more or less altered, and not unfrequently highly so, but sometimes there is no alteration whatever, and the rocks closely resemble the typical ones of the Raniganj field. The coal is an exception, as it everywhere has acquired the above flaky structure, even when the beds accompanying it have undergone no appreciable change.'

Mr. Bose re-examined certain localities in the Darjeeling district where the prospects for profitable working appeared better than at Tindharia. His explorations were at first restricted to an area 2¾ miles by three-eighths of a mile wide situated between the Lisu and Ramthi rivers. A number of attractive seams were found by Mr. Bose, and he calculated that 20 million tons of coal of good caking quality were available. Subsequently he examined the tract from the Teesta to Pankabari, but without making any discovery of other promising seams.

R. R. Simpson[1] states with regard to the exploitation of these Darjeeling Damuda coals:—

'The first and only attempt to work the coal on a commercial scale was undertaken by a Calcutta firm in 1896. A colliery was established at Daling and, until the abandonment of the enterprise in 1900, a total quantity of 7,231 tons of coal was raised.'

The details of output were 96 tons in 1896, 1,356 tons in 1897, 2,191 tons in 1898, 2,098 tons in 1899, and 1,490 tons in 1900.

In spite of this and of the facts that the coal is crushed and the seams dip at 30° to 45° northward, it is to be remembered that Mr. Bose recognised at least ten seams over five feet thick, and with less than 22 per cent. of ash in the Lisu-Ramthi area. This works out to over 100 million tons of coal in two square miles assessing 50

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 36, (1922).

feet of coal horizontal. With inclined seams the amount will be larger. Some of the analyses are worth quoting.

Analyses of Darjeeling Gondwana coals.

—	1	2	3	4	5
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	1·60	16·10	4·21	14·54	4·72
Volatile matter	10·40	15·47	14·09	8·86	22·16
Fixed carbon	61·76	51·85	62·56	63·96	60·24
Ash	26·24	16·58	19·14	12·64	12·88
Colour of ash	red.	red-grey.	brown.	grey.	..
Caking property	no.	cakes strongly.	cakes strongly.	cakes strongly.	..

It was found that surface samples did not possess caking properties, but that samples from five to six feet in depth were often of caking quality.

Localities :—

1. Ramthi valley (No. 30).
2. Churanthi (No. 25) from a depth of seven feet.
3. Churanthi (No. 7) from a depth of nine feet.
4. Lisu (No. 3).
5. Lisu (No. 1).

The occurrence of igneous intrusions of mica-peridotite, similar to those which have spoilt so much coal in the Damodar Valley coalfields, was noted by F. R. Mallet and confirmed by Mr. Bose. I have found these intrusions as far west as the exposures on the road from Tindharia to Chunbati and well exposed in the Teesta about Kalapani bungalow. In none of the sections seen by me is the coal likely to be worth exploitation for extensive use, but there is no reason why the coal near Tindharia might not be used as powdered fuel for local use in the adjacent tea factories, if suitable care is taken in working.

Probable Existence of Damudas beneath the Gangetic Alluvium.

The following extract is taken from Mr. Mallet's memoir (page 32) :—

'The occurrence of Damudas in the Darjiling Himalayas adds a wide expanse to the area within which these rocks are known to have been deposited, at least in patches. It is fairly inferable that such was the case over the country now occupied by the alluvial plains of the Ganges between Rajmahal and the foot of

the Darjiling hills, and extending for an unknown distance to east and west; and it is further probable that there still exist beneath those plains, coal-fields equal, perhaps, in value to those which now supply Bengal with fuel.

'The difficulties in the way of finding such are, however, manifest: *Firstly* the unknown depth of the Gangetic alluvium, which is certainly sufficient to make boring extremely expensive, and may be so great as to render mining impracticable; *Secondly*, the small proportion of the total area which, judging from our experience of the known coal-fields, the Damuda rocks might fairly be expected to occupy. There are indeed some reasons, founded on the connection observable in the position of the fields between Raniganj and the river Koel, with the present lines of drainage, for supposing that the Damudas were more largely deposited in the main Gangetic valley than in the higher lateral ones.'* Probably also the geographical position and geological features of the known coal-fields would furnish a clue pointing to some portions of the southern part of the plains as more promising than others. At the best, however, the work would be mainly haphazard, and entirely so beyond a limited distance from the edge of the plains. The first borehole *might* strike a field equal to the Raniganj, and *per contra*, lakhs of rupees might be spent with no return whatever. It may be safely predicted that for many decades no attempt will be made in this direction; but at some future epoch in the History of India, when her manufacturing industries shall have been fully developed, when the demand for coal shall have enormously increased, and the fields of the Damuda valley begun to show signs of exhaustion, it is quite conceivable that the winding engine and the cage will be seen in the midst of the alluvial plains of Bengal, where an unbroken expanse of rice-fields now stretches to the horizon.'

While these conjectures by Mr. Mallet are of great value in drawing attention to hidden coalfields, it is not to be forgotten that the evidence of gneissic inliers in the Assam Valley suggests very severe overthrusting in the Himalayan region and extensive erosion of the areas to the south *before* the Gangetic alluvium was laid down.

Gondwanas in Garo Hills.

Since this memoir went to Press, I have found evidence in the exposure at Singrimari (25° 44′ : 89° 54′) in the Garo hills, of Barakar-like sandstones, dipping westward into the Jinjiram river, intruded by three dolerite dykes, and in the occurrence in the *nala* behind the Bungalow of carbonaceous shales with lenticles of coal and numerous impressions of *Vertebraria indica*, proving the Damuda age of these beds beyond question. They had formerly been thought to be of Upper Cretaceous age. The coal (specific gravity, 1·678) contains 40·26 per cent. ash and cakes distinctly.

CHAPTER 5.

COALFIELDS OF BIHAR.

COALFIELDS OF THE RAJMAHAL HILLS.

The exposures of coal-bearing, Lower Gondwana rocks which constitute the coalfields of the Rajmahal hills trend southward along the line of the 87° 30′ meridian (east longitude), from just south of the Ganges river below Colgong to the More river near Suri—a distance of nearly 100 miles from north to south. West of the meridian stated, the rocks in general are gneisses and metamorphics of pre-Gondwana age. East of this line, the prevailing rocks are basaltic lava flows which have a gentle eastward dip and are covered with laterite just before they are hidden by the alluvium of the Ganges river. Corresponding roughly with the meridian and showing at intervals from beneath the basaltic lavas and, evidently, lying on the older rocks with marked unconformity, is an almost continuous outcrop of Gondwana strata. On a closer examination, it is seen that these Gondwana rocks are representatives of the Talchirs (in a few relatively small occurrences), five exposures of coal-bearing Damudas (Barakars), and a continuous strip of Dubrajpur beds just under the basaltic rocks. The infra-trappean Dubrajpur beds are thus seen to be more or less conformably below the basalts and to lie discordantly upon the Barakars and older rocks. The Dubrajpur beds are of Upper Gondwana age. The basaltic lavas comprise ten flows and must total nearly 1,000 feet. Some of the flows are separated by thin (ten to 30 feet) beds of shale and sandstone in which an abundance of plant fossils have been obtained. It is these few relatively insignificant inter-trappean plant beds with their rich fossil flora which really comprise the Rajmahal series.

The geology of the Rajmahal hills was studied many years ago by several observers, including Dr. W. T. Blanford about 1856-57, but the whole tract was mapped by Dr. V. Ball.[1] He found that the Damudas overlapped the Talchirs and that there were

[1] *Mem. Geol. Surv. Ind.*, XIII, Pt. 2, (1877).

possibly two divisions of the Damudas present in the exposures seen. However, the fossil evidence makes it almost certain that the coal measures at least are Barakars and not Raniganj in age. The great hiatus between the Damudas and the overlying Dubrajpur beds is of importance as there was enough time for very considerable denudation in Triassic times. And it is for this reason that opinions regarding the extension of the coal measures under the Upper Gondwana and trappean rocks must be treated with caution. From the evidence available in and around the exposed coalfields of the Rajmahal hills, it is almost certain that the coal measures are not uniformly present under the younger rocks, although they may be far more extensive than the exposed Damudas might lead one to suppose.

Northern Area near Ganges.

Damuda rocks are exposed about four miles N. N. E. and again eight miles east by south of Colgong. In the former locality near Akbarnagar (25° 4′ : 87° 50′), Mr. Simpson[1] states that a boring was put down in 1885 in the hope of finding coal, but after attaining a depth of 256 feet without finding coal or passing through the Barakar sandstones the attempt was discontinued. This boring therefore cannot be considered as having decided the question whether coal will be found below. There appear to be no particulars regarding the occurrence east of Colgong near Bara (25° 13′ : 87° 22′), but on the eastern side of the hills and within four or five miles of Rajmahal (25° 3′ : 87° 50′) and roughly north-west of the town, Barakar sandstones are seen. It is in this vicinity near Mangal Hat (25° : 87° 57′) that china clay is worked for supply to the Calcutta pottery works. Dr. Murray Stuart[2] also mentions other areas both for kaolin and glass sands in the Rajmahal hills. There is no record of coal having actually been met with in the northern part of these hills. Dr. Ball[3] has suggested other places where Barakar rocks probably occur, as at Turbuna on the east of the hills, and in the valley north-west of Burhait (Berhait; 24° 53′ : 87° 37′) in the centre of the hills.

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 38, (1922).
[2] *Rec. Geol. Surv. Ind.*, XXXVIII, p. 133, (1909).
[3] *Op. cit.*, p. 197.

Hura Coalfield.

The name appears to have been given to the spread of Damuda rocks which extend southward from Daria Chak (25° 7′ : 87° 22′) through Simra Bara (25° 2′ : 87° 22′) to near Kisma (24° 56′ : 87° 25′), along the west of the Rajmahal hills. Near Simra and to the north, there are outliers or intrusions of dolerite with the Damuda exposures. As the original village of Hura, now Lilatari, is shown on Ball's map to be on a hill of gneisses and the coal outcrops near the present village of Phulberia (24° 59′ : 87° 23′), it is not quite an appropriate name. Ball says that under the hill of Dakaita (25° 3′ : 87° 22′) there is a nine-foot seam of coal like that found in the *ghat* (pass) of Gandeswari Hill near the village of Bhaura Chhota (25° 1′ : 87° 23′). In the section there were seen about 12 feet of coaly shale or dull coal with carbonaceous shale.

Gilhurria or Jilbari Coalfield.

Near the Hura exposure several seams are visible and a certain amount of work was done there many years ago. Further south coal is exposed south of the village of Bhalgora (24° 57′ : 87° 25′), the exposure is obscure and what coal is seen is poor in quality and barely two and a half feet thick. Further south again and about four miles E. N. E. of Karmatanr (24° 9′ : 87° 20′), across a wide spread of Talchirs, Dr. Murray Stuart[1] discovered coal at Gilhurria (now Jilbari; 24° 51′ : 87° 24′) where it was being locally worked. He states that two seams were present. The upper seam is not less than six feet and consists of carbonaceous shale with fragments of carbonized wood. His proximate analysis of the coal is given below:—

	Per cent.
Moisture	7·46
Volatile matter	30·94
Fixed carbon	39·67
Ash	21·93

and shows that it is poor material.

Chuparbhita or Dhamni Coalfield.

The discovery made by Dr. Murray Stuart shows that in this region there is every indication of a continuity of the coal measures

[1] *Rec. Geol. Surv. Ind.*, XXXVIII, p. 149, (1909).

below the Upper Gondwanas and Rajmahal basaltic lavas from the Hura coalfield to that of the Dhamni (24° 47′ : 87° 28′) area 12 miles to the S. S. E. This Dhamni or Chuparbhita (from a pass five miles west of Dhamni) coalfield in the valley of the Gumani *nala*, is roughly seven miles long in a north-easterly direction down the valley from near Jiajori (24° 45′ : 87° 25′). In this area near Malikbathan, a mile south-east of Jiajori, a section showing two poor seams, nine feet and six feet of coaly shale, is to be seen. Further down the Gumani valley, a four-foot seam of stony black coal is exposed. An inferior seam of coal is also seen near Kesaphuli (24° 49′ : 87° 30′), two miles northward of Dhamni. Dr. Ball also mentions seams exposed near the village of Chhatgam a mile or so south of Dhamni; at Damro (24° 43′ : 87° 29′) still further south; and Dhaupahari (24° 44′ : 87° 25′); but he gives no details of the coal and it is probable that little can be seen clearly. The area might have been worth examination if the known coal of this Dhamni valley had been found of good quality.

Pachwara or Bansloi Coalfield.

The next area to the south in which coal measures of the Damudas (Barakars) occur is that of the Bansloi valley or Pachwara pass, 15 miles from the Dhamni area. This tract was re-examined by Mr. G. V. Hobson[1] in the field season 1928-29. He found coal was being worked in a small way in several places, chiefly about Bargo (24° 30′ : 87° 24′) and Sakalma near Chilgo (24° 33′ : 87° 28′). He was not, however, favourably impressed by its economic value owing to the poor quality of the coal, which is a long-flaming, non-caking coal only used for brick-burning. There appear to be no recent analyses of these coals, but they are all relatively high-moisture coals, and the average analysis of 15 samples from the Rajmahal hills given by Dr. Ball[2] shows 39·27 per cent. volatile matter, 44·17 per cent. fixed carbon and 16·56 per cent. ash on a moisture-free basis.

Mr. Hobson's work in the Bansloi or Pachwara field is of considerable interest, as he has shown that the igneous intrusions in this area are older than the faulting. He is quite certain that the intertrappean plant beds which constitute the Rajmahal stage lie

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 145, (1930).
[2] P. 82 (236) of his memoir.

between lava flows and not between sills. He has not found any so-called mica-peridotite intrusions in the area studied by him. These are points of difference from both the Raniganj field to the south and the Darjeeling Gondwanas to the north.

Mahuagarhi Tract.

Damudas of Madhuban, Narganj and Gopikandar.

From Amrapara (24° 36′ : 87° 34′) in the Bansloi valley and east of the Pachwara field, a ridge of trap stretches westward through Madhuban (24° 30′ : 87° 30′) to connect with the basaltic hill range known as Mahuagarhi Hill. Just south of Madhuban, there is an inlier of Damuda rocks which are clearly the continuation of the Pachwara coalfield, but are separated from it by the trap ridge of Madhuban. No coal seams appear to have been found in this tract, although it may be presumed that they do occur and are similar to those met with in the Pachwara or Bansloi valley to the north.

Immediately south of Mahuagarhi Hill (24° 29′ : 87° 24′) lies the so-called Mahuagarhi coalfield, the Damuda rocks in which are traceable east of Narganj (24° 26′ : 87° 24′) to near Gumra (24° 22′ : 87° 28′). The name Narganj can be best ascribed to this tract which follows along the west side of the Gumra *nala*, but the Mahuagarhi coalfield applies strictly to the northern part at the base of the hill of the same name. We know practically nothing of this area, as Dr. Ball refers to it very briefly, and according to older writers it is of little economic value.[1]

Gopikandar near Dubrajpur (which gives its name to the basal Upper Gondwana rocks of the Rajmahal hills) lies in the valley of the Tirpatia *nala* in which Damuda rocks are seen in two areas separated by a narrow strip of trap rocks. This Gopikandar, or Tripatia, tract is separated from the valley of the Gumra to the west by the ridge of Dubrajpur. The rocks exposed in the ridge are largely the basal Upper Gondwanas with outliers of trap, but the Damudas evidently pass below them from the Gumra to the Tirpatia side. Dr. Ball mentions an outcrop of carbonaceous shales which might be mistaken for coal, 2½ miles north of Gopikandar near Jhutichapar (24° 27′ : 87° 28′). No workable coal

[1] *See* LaTouche's Annotated Index, p. 84, (1918), under Dubrajpur.

seems to have been recorded from these Damudas of the area above Gopikandar in the Tirpatia valley.

Brahmani Coalfield.

The Damuda rocks seen on both sides of the Dubrajpur ridge, which trends south-east, re-appear from beneath the trap and basal Upper Gondwana rocks in the valley of the Brahmani (Bramini) river. Just below the junction of the Gumra *nala* with the Brahmani a strong fault throwing eastward brings in the Talchirs. These beds are followed downstream (eastward) by Damudas for nearly ten miles, in which coal seams and beds of carbonaceous shales are seen. The most promising area appears to be from Panchbahini to Saldaha, west and north-west of Sarsabad (24° 18′ : 87° 32′). Coal has also been recorded from south of the river, south-west of Masania (24° 16′ : 87° 33′), on the way to Harin Sing, and from just north of Saharbera (24° 14′ : 87° 34′) where the path from Masania for Paikdaha crosses the Brahmani. The trap comes into the river bed south-east of Taldiha (24° 16′ : 87° 36′) and conceals all the older rocks further down the Brahmani river. A small inlier of Damudas occurs at Ramgarh (24° 14′ : 87° 32′) on the road from Dumka to Rampur Hat. The hilly region to the south of the Brahmani river is called the Ramgarh hills after the locality abovementioned.

The strong north to south fault along the western side of the Brahmani field makes it different from the other Damuda areas of the Rajmahal hills. And it is made clear in this tract that not only is there the great hiatus between the Barakars and Dubrajpur beds, but that there is a discordance between the Dubrajpur beds and the overlying basalts of the Rajmahal series. In the Sarsabad area, the basalts rest directly on the Barakars.

Reserves of Coal.

Dr. Ball estimated that 70 square miles of Damuda rocks were exposed in the coalfields of the Rajmahal hills, and allowed a mimmum thickness of five feet of coal (workable) and calculated that 210 million tons of coal were available. This estimate suffers from the disadvantage that it is given without the detailed particulars on which it depends. It may be stated in general terms that the boring results in the Hura coalfield showed two seams of poor coal,

one of four feet and the other of 16 feet. It is certain that the coal measures occur at accessible depths under a far larger area than given above, but nevertheless the information to hand shows that the Rajmahal coal from the exposed coalfields is not attractive in quality even on a moisture-free basis.

Coal Production from Rajmahal Hills Coalfields.

Dr. T. Oldham has given[1] the following returns for coal production from the fields in the Rajmahal hills: 219,000 maunds in 1858, 757,000 mds. in 1859, 1,234,860 mds. in 1860, 63,935 mds. in 1861, 44,329 mds. in 1862, and 300 mds. in 1863. All this activity came to an end in 1863, but coal was again exploited before 1890. Dr. Ball gives no reference to any output in 1879[2]; but the production in the three years previous to 1890 averaged 125 tons from Domanpur and Ghatchora, while in 1890 the production from these places is given as 200 tons.[3] Workings in a small way for local use have continued since, but it has been computed that perhaps not more than 100,000 tons has been raised from the Rajmahal coalfields.[4] The statistics since 1898 are available in the *Records of the Geological Survey of India*, except the period 1915-1918, when from some misunderstanding the returns were included in those of the Bokaro coalfield. The details since 1898 are as below:—

Year.	Tons.	Year.	Tons.
1898	423	1907	257
1899	412	1908	333
1900	397	1909	1,900
1901	436	1910	2,788
1902	219	1911	1,978
1903	335	1912	2,775
1904	274	1913	3,572
1905	414	1914	8,145
1906	577		

[1] *Mem. Geol. Surv. Ind.*, VII, p. 149, (1871).
[2] Manual of the Geology of India, III.—Economic Geology, p. 595, (1881).
[3] *Imp. Inst., Hd.-Bk. Com. Products*, No. 9 Indian Coal, p. 24, (1893).
[4] *Mem. Geol. Surv. Ind.*, XLI, p. 40, (1922).

Since 1919 the output has been as follows :—

Year.	Tons.	Year.	Tons.
1919	1,909	1927	1,488
1920	960	1928	636
1921	2,170	1929	565
1922	2,801	1930	445
1923	2,635	1931	1,699
1924	..	1932	1,500
1925	1,653	1933	1,752
1926	1,788		

Tangsuli Basin.

Damudas of Tangsuli, four miles from Suri.

Outside the Rajmahal hills proper and lying between the Brahmani and Adjai rivers, there is a small area (two square miles) of Damuda (Barakar) rocks on the north of the Mor (or Morakhi) river, a few miles north-west of Suri (23° 55′ : 87° 32′); the area occurs north of the village of Tangsuli (23° 58′ : 87° 29′). Dr. Ball was in no doubt that the rocks exposed (pebble beds, grits, sandstones, carbonaceous shales and thin strings of coal) were Barakars. No Talchirs were seen and the boundaries are somewhat obscured by laterite. The nearest point of the Rajmahal traps and Dubrajpur beds from the Tangsuli outlier of Damudas is about seven miles away to the north-east near Deocha (24° 2′ : 87° 35′) on the Dwarka river. The Damuda rocks of the Adjai river are less than 20 miles away to the south-west of the Mor river at Tangsuli. And to the west the nearest exposure of Barakar coal measures is the Kundit Karaia field, less than 30 miles away, with an outlier of Talchirs between. It is thus seen that besides extending south from the Ganges river below Colgong, the Lower Gondwana rocks of the Rajmahal area very probably connected with Raniganj and Giridih.

DEOGHUR COALFIELDS.

The existence of Damuda coal measures in the tract between the Giridih (Karharbari) coalfield and the Rajmahal hills was

established by the Geological Survey of India in 1853. Writing in 1870, T. W. H. Hughes[1] stated :—

'The coal which is found at Sahajori was assayed by Dr. Waldie of Barnagore, and contained 28 to 37 per cent. of ash. I believe it to be an average sample of the coals occurring in the three outliers, with the possible exception of one in the smaller outlier lying to the east of the Adjai.'

According to the map given with Mr. Hughes' memoir, there are several outliers of Talchirs and four with associated Damuda rocks in the area from near Jamjuri (24° 3′ : 87° 1′) in the Sidhisari valley north-westward to the vicinity of Goradih (24° 12′ : 86° 33′) just south of the Jainti river in the Santal Parganas. The largest of these Gondwana outcrops is crossed by the East Indian Railway, main line, south of Madhupur near Karon (24° 7′ : 86° 45′). It is called the Jainti coalfield from the river which drains it.

Kundit Karaia Coalfield.

This is the most easterly of the coal measures of the area under consideration. Only two thin seams of coal were met with in this area near Khairbani (24° 3′ : 86° 59′). Two dolerite dykes cross the field from east to west. The measures are cut off to the south by a strong E. S. E. fault which throws northward. The field appears to be of no serious value for coal.

Sahajuri Coalfield.

This outlier is named after the village of Sahajuri (24° 8′ : 86° 51′) in its north-western tract. It was in this vicinity that early development began, but the results were very disappointing and Mr. Hughes was satisfied that the coal met with was relatively high in ash. However, he mentions a 'burnt ridge that may indicate coal' immediately south of Dudhi Chuan, about a mile E. S. E. of Sahajuri. Trials were made by sinking pits near Tarabad (24° 6′ : 86° 53′) without satisfactory results. The field is sliced by a strong east-south-east fault, but is relatively free from dykes.

[1] *Mem. Geol. Surv. Ind.*, VII, p. 248, (1870).

Jainti Coalfield.

This, the most important of these outliers, has a superficial extent of barely five square miles of Damuda (Barakar) rocks. The field is cut off along the north by a strong east by south fault which throws south, and is cut in half by a north-west fault. The western end of the field is traversed by a large dolerite dyke, and the coal measures are known to have been pierced by intrusions of mica peridotite. There appear to be three seams of coal of workable thickness in the Banskupi part of the field, but their quality is not uniform. However, some of the coal, which looks like that of the lower seam at Giridih, is of fair to good quality. Coal had previously been worked in this field near Madankata, Kathmirki and Pahardah. The following analyses from Villiers Jainty Central Colliery for the Coal Grading Board, by the Alipore Test House, are of considerable interest :—

——	1	2	3	4	5
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture . .	3·10	4·10	5·60	4·00	5·20
Volatile matter .	22·80	27·50	27·50	28·20	24·35
Fixed carbon .	58·30	59·70	61·90	58·90	57·70
Ash . . .	18·90	12·80	10·90	12·90	12·75
Calorific value (calories).	6,637	7,018	7,215	7,015	..

Samples dated 19th February, 1926.

1. Top seam, 5 feet 6 inches thick.
2. Middle seam, seven feet thick.
3. Bottom seam (old area), about 4 feet 4 inches of thickness.
4. Bottom seam (new area), No. 9 pit.
5. Old analysis (1882), Jainti river, at E. I. Ry. (Madhan Katta).

Although the calorific value, shown in calories, is estimated on a moisture-free coal, it is none the less clear that the coal is of good quality in the Bottom seam, which might quite possibly be related to the lower Karharbari seam of Giridih. The Middle seam is also attractive if this quality is maintained. Unfortunately the area is small and the presence of mica-peridotite intrusions render it possible that some of the coal will be spoilt.

The Jainti field was evidently opened about 1886 near Madankata. The production for the three years 1887 to 1889 is given as 24,448 tons and for 1890 as 35,344 tons. It is probable that the production from this field has been included in either the Rajmahal hills or that portion of the Raniganj field in the Santal Parganas. In 1895 the output from the Santal Pargana coalfields is given as 32,172 tons; in 1896 as 1,640 tons and in 1897 as 2,879 tons. In 1898 there is no return for the Santal Parganas but 423 tons for the Rajmahal hills. The next definite output for the Deogarh (Jainti) coalfield is from 1914 when the production was *nil*. Later production has been :—

Production.

Year.	Tons.	Year.	Tons.
1915	40,730	1925	76,680
1916	75,089	1926	82,604
1917	86,894	1927	56,724
1918	140,373	1928	48,059
1919	152,941	1929	40,732
1920	118,651	1930	43,580
1921	105,652	1931 . .	50,178
1922	96,612	1932	43,163
1923	82,166	1933	43,530
1924	78,547		

Baghdaru Outlier.

A small area of Barakar rocks is marked on Hughes' map across the Baghdaru *nala*, a mile south of Kharjori (24° 12′ : 86° 38′), and about three miles west of Banskupi. The area is traversed by at least two dolerite dykes and no coal seams have been encountered. Even if coal were found, the area is so small that it could hardly be of any importance.

In addition to the outliers of Barakar rock seen in the Santal Parganas of this region of Sarath-Deogarh and Jamtara (including Kundit Karaia), perhaps more remarkable are the areas of Talchirs. One occurs near Makranda (24° 1′ : 87° 37′) in the Sidhisari valley, barely five miles north-west of Kundahit. There are four down the Adjai valley from Alaura (24° 13′ : 86° 46′), five miles west

of Sarath; another at Alakbera (24° 8′ : 86° 48′), below the junction of the Jainti and Adjai rivers; a third at Ghusi (24° 4′ : 86° 49′), and two small ones near Barchandi (24° : 86° 50′). There is a large outlier in the valleys of the Damgari and Pichri *nalas*, above and below Ladudai (24° 6′ : 86° 30′), and at least three up the Barakar river from east of the Dhanbad-Giridih road at Partapur (24° 2′ : 86° 26′) to the Giridih-Dumri road (24° 7′ : 86° 13′) three miles below and on to the confluence of the Irga and Barakar rivers at Bardarha (24° 11′ : 86° 7′). This brings us to the Giridih (Karharbari or Kurhurbali) coalfield.

HAZARIBAGH COALFIELDS.

Giridih or Karharbari Coalfield.

This small area of Lower Gondwana rocks was brought to notice by Dr. J. McClelland in 1848, but it was known that coal occurred there before that date. Dr. McClelland's report was published in 1850. The area was visited by Dr. T. Oldham in 1852 and mapped under his direction by Mr. W. L. Willson in 1859. Unfortunately the topographical maps then available were so incorrect that it was thought best to have the field re-surveyed by Mr. T. W. H. Hughes when better maps were available. Mr. Hughes' report [1] was published in 1870. The fossil flora of the lower coal measures has long attracted attention and was studied by Dr. O. Feistmantel [2] as long ago as 1875. The coalfield was described by Dr. W. Saise [3] and has received brief notice from time to time since with regard to the excellence of the coal from the Lower Karharbari seam, or in connexion with the effects of the igneous intrusions (dolerites and mica-peridotites) which traverse the coal measures.

The rocks exposed consist of an outlier of Talchirs and Barakars among the gneisses of Hazaribagh. The dykes above referred to are intrusive into these Lower Gondwana strata. The area covered by the Gondwanas is barely 11 square miles, of which only seven are occupied by productive coal measures. The area is partly in *mouza* Karharbari of the Giridih subdivision of Hazaribagh. The town of Giridih (24° 12′ : 86° 18′) is situated on gneisses on the

[1] *Mem. Geol. Surv. Ind.*, VII, Pt. 2, (1870).
[2] *Rec. Geol. Surv. Ind.*, IX, (1876), and XXII, pp. 73-74, (1889), and in particular *Pal. Ind.*, Ser. XII, Vol. III, (1879).
[3] *Rec. Geol. Surv. Ind.*, XXVII, p. 86, (1894).

south side of the Usri *nala*, at the north-east corner of the field. The whole of the drainage of the field is southward into the Barakar river, barely six miles south-west from Giridih. The field is situated between two main east to west faults and is cut by a third parallel fault which throws southward, making the southern part of the field rather richer in Barakar coal measures and larger in area. The Talchirs show up both to the east and west ends of the field—especially in the western part of the northern area, where an inlier of gneisses also occurs. As in the case of the Deogarh or Karon coalfields, so here there are younger rocks than the Barakars (other than the intrusions).

The workable seams are divided into two groups—the Karharbari (lower and upper) and the Hill seams. The upper Karharbari seam of four to ten feet thickness may be considered as now exhausted. The Lower Karharbari seam varies considerably both in thickness and in quality. At the Deep Pit the seam is 24 feet thick at a depth of 840 feet; 19 feet at North Central Pit No. 2 at a depth of 340 feet roughly; 18 feet at Bitagarha at a depth of 222 feet; in two seams of five feet and 9 feet 6 inches with a stone parting of three feet at Jubilee Pit at a depth of 772 feet; and ten feet at Ramnadih at a depth of 150 feet. The coal from this seam is one of the finest caking coals in India (for the preparation of metallurgical coke).[1]

Lower Karharbari seam.

Typical analyses of the coal from the Lower Karharbari seam are given below :—

Analyses of samples from Ramnadih pit, Karharbari Colliery, Giridih.

——	Top of seam.	Middle of seam.	Bottom of seam.
	Per cent.	Per cent.	Per cent.
Fixed carbon	66·61	60·72	64·19
Volatile matter	21·10	24·80	25·20
Moisture	1·80	1·40	1·40
Sulphur	0·49	0·48	0·41
Ash	10·00	12·60	8·80

[1] *See Rec. Geol. Surv. Ind.*, LIX, p. 371, (1926).

Details of the ash, given as percentages, of the Ramnadih coal.

—	Top of seam.	Middle of seam.	Bottom of seam.
	Per cent.	Per cent.	Per cent.
Silica	7·08	8·290	4·963
Alumina	1·840	3·094	2·544
Ferric oxide	0·60	0·647	0·728
Manganese oxide	0·093	0·117	0·130
Lime	0·140	0·126	0·140
Magnesia	0·108	0·181	0·139
Phosphorus pentoxide	0·022	0·027	0·019
Sulphur trioxide	0·008	0·020	0·012
Alkalies, etc.	0·109	0·094	0·121
NOTE.—The sulphur trioxide in the ash re-calculated to the coal is misleading.			
Phosphorus in coal	0·01	0·012	0·009

Average of samples for full thickness, ten feet, of seam :

	Per cent.
Ash	10·47
Phosphorus	0·010

(Analyses by A. Dawes Robinson.)

Analyses of samples from Bilagarha pit, Karharbari Colliery, Giridih.

—	Top of seam.	Middle of seam.	Bottom of seam.
Fixed carbon	63·16	65·15	50·95
Volatile matter	23·00	28·10	19·80
Moisture	1·40	1·50	1·40
Sulphur	0·44	0·45	0·45
Ash	12·00	4·80	27·80

Details of ash, given as percentages, in the Bitagarha coal.

—	Top of seam.	Middle of seam.	Bottom of seam.
Silica	7·488	2·784	14·905
Alumina	3·432	1·334	8·463
Ferric oxide	0·480	0·475	2·650
Manganese oxide	0·111	0·044	0·202
Lime	0·072	0·067	0·328
Magnesia	0·129	0·037	0·353
Phosphorus pentoxide	0·013	0·015	0·013
Sulphur trioxide	0·019	0·008	0·049
Alkalies, etc.	0·254	0·075	0·421
NOTE.—The sulphur trioxide in the ash re-calculated to the coal is misleading.			
Phosphorus in coal	0·0057	0·007	0·0063

Average of samples for full thickness, 18 feet, of seam :

	Per cent.
Ash	14·73
Phosphorus in coal	0·0063

(Analyses by A. Dawes Robinson.)

Analyses of samples from Jubilee Pit, Karharbari Colliery, Giridih.

—	Top of seam.	Middle of seam.	Bottom of seam.
Fixed carbon	64·34	65·94	69·53
Volatile matter	26·50	25·50	23·50
Moisture	1·40	1·20	1·60
Sulphur	0·36	0·36	0·37
Ash	7·40	7·00	5·00

Details of the ash, given as percentages, in the coal of Jubilee Pit.

——	Top of seam.	Middle of seam.	Bottom of seam.
	Per cent.	Per cent.	Per cent.
Silica	5·032	3·92	2·94
Alumina	1·740	1·84	1·26
Ferric oxide	0·232	0·84	0·520
Manganese oxide	0·068	0·071	0·051
Lime	0·133	0·084	0·060
Magnesia	0·077	0·110	0·082
Phosphorus pentoxide . . .	0·013	0·015	0·0055
Sulphur trioxide	0·013	0·011	0·009
Alkalies	0·078	0·099	0·072
NOTE.—The sulphur trioxide in the ash re-calculated to the coal is misleading.			
Phosphorus in coal	0·0059	0·007	0·0025

All coking coals.
Average of samples for thickness 14 feet 6 inches of seam :—

	Per cent.
Ash	6·47
Phosphorus in coal	0·0052

(Analyses by A. Dawes Robinson.)

The coal is a curious dull variety which at one time was thought to be characteristic only of this seam in this field, but subsequent work has shown that many of the Lower Barakar seams of the Jharia coalfield have coal of similar appearance, although not of such good quality.[1] Microscopic examination of thin slices of this coal has revealed distinct woody texture, suggestive of accumulated drifted logs, which would thus account for the good quality. Coke-making experiments made many years ago [2] and practised since at Giridih have proved the value of this coal, both in coke-making and in the recovery of valuable by-products—tar, benzol, and sulphate of ammonia.

Dr. T. Oldham, in his report on the 'Coal Resources and Production of India', for Government (1867) states that before 1863

[1] *See* also *Mem. Geol. Surv. Ind.*, LVII, pp. 41 and 150, (1931).
[2] *Rec. Geol. Surv. Ind.*, XXXI, p. 102, (1904).

Reserves of coal in the Karharbari coal-fields.

the coal was carted to the Ganges. He estimated the area at 10 square miles less one-fifth, *i.e.*, 8 square miles and 27 feet of coal= 223 million tons. Excluding one-fourth for losses, etc., he gave the reserves of the field at 168 million tons of coal. Mr. Hughes had estimated in 1870 that the available coal in the Karharbari (Giridih) coalfield might be taken as 105 million tons (average of 15 feet of coal over seven square miles, and that, allowing one-third of this for waste and loss by intrusions, there was a total of 80 million tons. Nearly 25 years later Dr. Saise, in 1893, summed the situation of reserves as below :—

	Tons.
Lower Karharbari seam	112,836,712
Upper Karharbari seam	1,412,600
Bhaddoah main „	4,083,840
Other hill seams	5,615,250
TOTAL	123,988,402

As far as can be ascertained, the production of coal from the Giridih (Karharbari, Kurhurbari or Kurhurbali) coalfield has been as follows :—

Year.	TOTAL FIELD.	Year.	TOTAL FIELD.
	Tons.		Tons.
1850 to 1857	Small.	1875	..
1858	147	1876	..
1859	3,973	1877	..
1860	10,108	1878	..
1861	9,684	1879	336,326
1862	10,123	1880	..
1863	932	1881	..
1864 to 1870	*no production.	1882	..
1871	Re-opened.	1883	..
1872	..	1884	..
1873	..	1885	..
1874	..	1886	..

Year.	E. I. R. Collieries.	Total Field.	Year.	E. I. R. Collieries.	Year.	Total Field.
	Tons.	Tons.		Tons.		Tons.
1887 .	..	..	1911 .	632,778	1911 .	704,443
1888 .	..	..	1912 .	663,841	1912 .	730,530
1889 .	..	..	1913-14 .	875,807*	1913 .	806,810
1890 .	..	506,565	1914-15 .	716,927	1914 .	825,026
1891 .	342,452	..	1915-16 .	811,099	1915 .	872,647
1892 .	365,672	..	1916-17 .	764,793	1916 .	866,055
1893 .	383,587	..	1917-18 .	704,005	1917 .	824,007
1894 .	391,214	..	1918-19 .	784,168	1918 .	846,592
1895 .	442,348	637,661	1919-20 .	806,960	1919 .	950,045
1896 .	473,824	666,919	1920-21 .	774,403	1920 .	831,293
1897 .	454,020	660,665	1921-22 .	672,410	1921 .	818,580
1898 .	416,543	653,047	1922-23 .	604,616	1922 .	659,101
1899 .	462,543	628,777	1923-24 .	674,270	1923 .	713,608
1900 .	528,374	712,727	1924-25 .	692,134	1924 .	768,690
1901 .	561,168	694,806	1925-26 .	763,622	1925 .	786,642
1902 .	613,789	776,656	1926-27 .	755,319	1926 .	818,681
1903 .	600,091	766,871	1927-28 .	777,250	1927 .	855,253
1904 .	585,437	773,128	1928-29 .	746,286	1928 .	804,118
1905 .	618,084	829,271	1929-30 .	645,510	1929 .	771,165
1906 .	623,979	803,321	1930-31 .	645,198	1930 .	613,533
1907 .	616,778	750,374	1931-32 .	647,222	1931 .	713,133
1908 .	671,743	782,763	1932-33 .	569,934	1932 .	583,243
1909 .	588,341	704,593	1933-34 .	(*a*)	1933 .	635,924
1910 .	559,535	679,304				

* January to March, 1913, and 1913-14.
(*a*) Not yet available.

So far as I know, very little coal has been taken from the Hill seams, and the Upper Karharbari seam may be taken as worked out, although all has not been extracted. Our estimates only concern at present the Lower Karharbari seam. Dr. Saise's data, after allowing for losses and extraction, gave a total of available coal in the field at the end of 1893 as 82,633,302 tons. And his

estimate for the coal in the Upper and Lower Karharbari seams in the property of the East Indian Railway Company only was 58,272,748 tons. He computed that on an yearly output of 600,000 tons the life of the whole field was 138 years from 1894.

The output has averaged nearer 750,000 tons without allowing for loss in working or coal left in pillars, etc. But assuming that the bare figure of 750,000 tons yearly the extraction for the last 40 years is of the order of 30,000,000 tons. This subtracted from 82,633,302 tons leaves a balance of over 52 million tons in the whole field. In addition to the 25 per cent. loss allowed for in 1893 by Dr. Saise, he also made an allowance for a further ten per cent. loss in actual extraction. If this ten per cent. is again taken, there is another three million tons to be deducted for the last 40 years' working. This would lower the total available in the whole field to about 49 million tons. And if we restrict the figures to the Karharbari seams only by deducting the Bhaddoah main and Hill seams, the reserves to the end of 1932 should be roughly 40 million tons. This extracted at 800,000 tons a year will last 45 years (allowing the ten per cent. extra loss admitted by Dr. Saise[1]). Six years ago I tried to show that nine million tons of excellent coal had been located in the State Railway concession at Giridih.

It is to be noted that of a total of 4,485 acres of Barakar rocks, no less than 3,341 acres lie in the concession of the East Indian Railway Company, and from the remarks in paragraphs above, it is seen that the reserves of coal in the Upper and Lower Karharbari seam outside the State Railway property in 1893 was probably under 16 million tons—seeing that two-thirds of the Hill seams and Bhaddoah main were within the concession. According to an estimate made this year (1933) by Mr. H. Lancaster, Superintendent, State Railway Collieries, Giridih, and submitted to the Chief Mining Engineer, Railway Board, the available coal in the Company's concession to-day is, after making allowances for losses, estimated at about 20 million tons. It is not exactly known how much of the 16 million tons outside the concession has been extracted by those working since 1893. The evidence as whole suggests that the 45-year life indicated above is optimistic, and that the reserves to-day in the Lower Karharbari seam are nearer 30 than 35 million tons in the whole field. The life of the field may perhaps quite safely be placed at not more than 25 years.

[1] *Rec. Geol. Surv. Ind.*, LIX, p. 291, (1926).

Chope Coalfield.

Barely ten miles west of Hazaribagh and about six miles north of the northern edge of the Karanpura coalfield, a small area of Talchirs and Barakar coal measures is seen in the bed of the Mohani (Mohana) river, two miles downstream from the Hazaribagh-Simaria road. These coal measures appear to have been discovered in 1869 by Dr. J. M. Coates of Hazaribagh and brought to the notice of Government soon after. The area was examined and mapped by Dr. V. Ball.[1] The position of the coal measures is exactly a mile and a quarter south of Chope village (24° 2′ : 85° 14′) in the Mohani river. These Lower Gondwana rocks are brought in by a strong east-by-south to west-by-north fault, which throws to the north and passes below (north of) the junction of the tributary nala from the west between Torar and Angara. The village of Chope is on gneissic rocks.

The only rocks seen in the field are Talchirs and Barakars. There is a dome in the middle of the field in which an inlier of Talchirs shows up and further reduces the area of coal-bearing beds. Only four feet of coal in one seam appears to have been found. The amount of the coal is evidently small and strictly limited. The quality is said to be poor. It is significant that since then very little work appears to have been done in this field. Dr. Ball himself recommended the people of Hazaribagh to obtain their supplies of coal from the Karanpura coalfield.

Itkhori Coalfield.

Roughly 25 miles down the Mohani river from the Chope coalfield and extending westward for three and a half miles west from the village of Itkhori (24° 18′ : 85° 9′), there is a narrow strip of Talchirs with a small area of coal measures (Barakars), on the east bank of the Mohani, within three miles and north-west of Ithkori village. These coal measures are cut off along the north by a south-throwing fault which trends west by north. The area came to the notice of Major Boldam, Deputy Commissioner of Hazaribagh, due to a quarrel between two petty zemindars. It was mapped by T. W. H. Hughes.[2]

[1] *Mem. Geol. Surv. Ind.*, VIII, p. 347, (1872).
[2] *Ibid.*, p. 321.

Mr. Hughes recognised three coal seams. The lowest or Mohani seam is eight feet thick, and the second four feet thick, and the top seam is not clearly exposed. The four-foot seam was considered the best in quality. The quantity of coal in the field was estimated at about 1,500,000 tons. Itkhori is on a good road about ten miles from Chauparan which is on the Calcutta Benares Grand Trunk Road. As the ash of the coal was thought to be high, little appears to have been done since then, but it is probable the coal would be suitable for local use in brick burning, etc.

Other Possible Outliers between Giridih and Daltonganj.

These little outliers of Lower Gondwana rocks at Chope (R. L. 2,018 feet) and Itkhori (R. L. 1,358 feet), lying as they do midway between the Giridih and Daltonganj coalfields, introduce the possible existence of other small areas of coal measures. It is known, for example, that three or four fair-sized outliers of Talchirs occur 30 miles north-west of Giridih in the valley of the Kunda *nala* near and south of Bhandari, three miles south-west of the well-known mica locality of Tisri (24° 35′ : 86° 4′). Another occurs south of Amjhar (24° 32′ : 86° 2′). A third occurs a mile south-west of Kisgo (24° 28′ : 86° 2′). It is many years since the intervening country has been geologically re-examined, but it is possible that other outliers of Talchirs and perhaps small areas of coal measures may occur, although it is most unlikely that any coalfield of economic value exists in this tract of gneissic rocks.

It is significant that the greatest spread of Gondwana rocks lies in the valley of the Damodar river, which, as has been suggested earlier, follows the trough of an old rift valley. No Upper Gondwana rocks have been discovered north of the Damodar valley in the country under consideration, until the area of the Rajmahal hills. In this country, also, the Raniganj series and the Panchets are not present. And the Dubrajpur beds are considered as the equivalents of the supra-Panchets or so-called Mahadevas of the Damodar valley (of Panchet Hill, Lugu Hill and Batuka Hill, in the Raniganj, Bokaro and Karanpura coalfields respectively).

Enormous Erosion of Gondwanas in Bihar.

In the Rajmahal hills, it is clear that the Lower Gondwanas (the Raniganj and Panchet series) had been subject to consider-

able erosion before the overlying Dubrajpurs were laid down. As the representatives of the Dubrajpur beds are still preserved in the Damodar valley and, as the Rājmahal beds have representatives on the East coast, it is probable that they were also present in the Damodar valley. It is thus possible that during the great Triassic land elevation, all the Raniganj and Panchet beds outside the Damodar valley tract were removed; and that since the Jurassic period all the Rajmahal plant beds and traps have been swept away from the areas outside the Rajmahal hills. If all the beds were originally present in the area of the Hazaribagh coalfields, it means that 5,000 feet of Lower Gondwanas were removed in the Triassic period and 2,000 feet of Upper Gondwanas and traps have been denuded since the close of the Jurassic period, or at all events since the lavas were poured out. To this total must be added an unknown thickness of older rocks. In the case of the relict mass of Parasnath Mountain, there is evidence of the removal of nearly 4,000 feet of gneisses and other Archaean rocks about Topchanchi and Dumri.

CHAPTER 6.

COALFIELDS OF BIHAR—*contd.*

DAMODAR VALLEY COALFIELDS—*contd.*

It has been the custom in times past to speak of the *Burdwan coalfield* and even to-day it is not unusual to meet with the expression *Bengal coalfields.* The name Burdwan coalfield was used for that part of the Raniganj coalfield east of the Barakar river (roughly east of 86° 45′E) in the Burdwan district; it was chiefly used in connexion with the coal mines in and around Raniganj (23° 36′ : 87° 7′) itself. The term Bengal coalfields is difficult to define now. In the mineral returns of 1858 to 1868 given by Dr. T. Oldham[1] no such term as Bengal coalfields is used; but under the caption 'Coal raised in Bengal'[2]. all the production (other than the Central Provinces) from the Raniganj coalfield, the Rajmahal Hills, the Khasia Hills (Assam) and Santhalia (Bokaro, Kotah, Kurhurbali and Palamau) is included. In 1879 Dr. V. Ball[3] definitely includes the production of coal mines in Burdwan, Hazaribagh, Palamau (Daltonganj) and Manbhum in Bengal. In 1890[4] we have collieries of Burdwan, Bankura, Hazaribagh, Manbhum, Palamau and the Sonthal Parganas in Bengal. And in 1900 Sir Thomas Holland[5] has the coalfields of Daling (Darjeeling District area), Daltonganj (Palamau), Giridih, Jharia, Rajmahal and Raniganj in Bengal. Since the separation of Bihar and Orissa from Bengal in 1912, only the Darjeeling area and part of the Raniganj coalfield are in Bengal. In fact the production returns from the Raniganj (and Trans-Adjai part of it) fall into the following districts:—Burdwan, Bankura, Manbhum, Birbhum and the Sonthal Parganas, of which only the first two are in Bengal. Sir Henry Hayden[6], when discussing the coal resources of India, states that the term 'Bengal Coalfields'

[1] *Mem. Geol. Surv. Ind.*, VII, pp. 146-150, (1871).
[2] *Op. cit.*, p. 133.
[3] 'Manual of the Geology of India, III,—Economic Geology', p. 595, (1881).
[4] *Imp. Inst. Hd.-Bk., Indian Section*, No. 9 Indian Coal, pp. 22-24, (1893).
[5] *Rec. Geol. Surv. Ind.*, XXXII, p. 29, (1905).
[6] 'The Coal Resources of the World', Vol. I, p. 355, footnote, (1913).

refers collectively to the fields in the original province of Bengal and included the following :—(1) Raniganj, (2) Giridih, (3) Jharia, (4) Bokaro, (5) Karanpura, (6) Hutar and Aurunga, (7) Daltonganj, (8) Rajmahal and (9) Darjeeling. To-day these names Burdwan and Bengal coalfields are best eliminated. In this chapter the coalfields in the valley of the Damodar river (sometimes called the Deonad in its upper reaches in the Karanpura field) include the Raniganj, Jharia, Bokaro, Ramgarh and North and South Karanpura fields and may be referred to collectively as the Damodar Valley coalfields.

The Raniganj coalfield in the Burdwan district of Bengal might be said to begin at the first exposure of laterite encountered after leaving Burdwan and at about mile 112 on the Grand Trunk Road to Benares. In the Burdwan district (Bengal) limits, the field extends to the Barakar river at mile 149 on the Grand Trunk Road. However, the Gondwanas extend much further west, namely to north of the Barwa Inspection Bungalow at mile 161 on the Grand Trunk Road. The next coalfield to the west, Jharia, begins at a longitude which on the Grand Trunk Road corresponds with the position of the old Kanra Inspection Bungalow at mile 171. And the western end of the Jharia coalfield corresponds with the longitude that passes through the peak of Parasnath. Recent surveys have shown that the western end of the Jharia coalfield in the Damodar valley is separated from the Gondwanas of eastern Bokaro by barely two miles of gneisses. The western ends of the Bokaro and Ramgarh coalfields also are almost in touch with the Gondwanas of the North and South Karanpura coalfields. Further west, although the gneissic gaps are larger, the North Karanpura field is almost as close to the Aurunga field as Jharia is to Bokaro. The Aurunga field in turn approaches the Hutar coalfield to the west nearly as closely as do Jharia and Raniganj.

Mr. E. R. Gee has very kindly prepared me a summary of the Raniganj field based on his memoir[1], to which the reader is directed for detailed particulars on this the largest and longest known coalfield in India. One point requires explanation, however, which is that the subdivisions of the Damuda strata in the Raniganj coalfield follow that originally adopted by Dr. W. T. Blanford. In addition Mr. Gee has found it necessary to make two important admissions and an important change.

[1] *Mem. Geol. Surv. Ind.*, LXI, (1932).

Damudas of Raniganj and other Coalfields.

The Damudas of the Raniganj coalfield are probably not less than 6,500 feet thick and are about 6,000 feet in the Jharia field gradually decreasing in the Bokaro and Karanpura coalfields to less than half these thicknesses. The Barakar series is well developed in each of the Damodar Valley coalfields, but as a coal-bearing formation it is inferior to the Raniganj series in the eastern part of the Raniganj coalfield. In the western area of the Raniganj field and in the Jharia, Bokaro and Karanpura coalfields, the Raniganj series not only becomes thinner, but also less and less of a coal-measure series as we go west up the Damodar valley. The strata between the Raniganj series and the Lower Damudas, or Barakars, were thought to be a valuable iron-ore series unconformable to the Barakars; and with these points in mind, Dr. Blanford separated them as the Ironstone Shales.

For several years it has been evident that the term Ironstone Shales is, even in the Raniganj field, somewhat misleading because the so-called iron-ore represents the weathered hematite and limonite of original siderite in the carbonaceous shales which, in an unweathered and unconcentrated form, is of little use as an iron-ore. Next it has been demonstrated in the field [1] that the so-called Ironstone Shales at Begunia are not unconformable to the Barakars and must be included in the Barakars, or at all events are separable from the true Ironstone Shales of Kulti. Mr. Gee has so treated them in his memoir and called them the Begunia shales, thus making one definite inroad on Dr. Blanford's classification. He has, further, also taken the Begunia sandstones, which overlie the Begunia shales, and placed them with the Barakars, thus removing two subdivisions from the original Ironstone Shales. It is largely to avoid confusion in the nomenclature of the Raniganj field that the term Ironstone Shales has been retained.

Barren Measures.

In the Jharia and Bokaro coalfields, it is possible to recognise an upward conformable series without workable coal seams above the Barakars. This is also true in the Karanpura coalfields. In consequence of this I separated, as a Middle Damuda or Barren

[1] *Rec. Geol. Surv. Ind.*, LX, pp. 363-364, (1928).

Measure series in the Jharia field, all the beds above the uppermost workable coal seam of the Barakars up to the lowest workable coal seam of the Raniganj series. These strata (termed the Barren Measures) are found to be divisible into four stages. Mr. Gee and I also distinguished four corresponding stages in the Raniganj coalfield. And these subdivisions are shown in our respective memoirs.[1] In view of several enquiries by students and teachers in Indian colleges as to which is to be regarded as the recognised official grouping of the Damudas, it is necessary to say that neither Ironstone Shales nor Barren Measures should be used for rocks outside the Raniganj and Jharia coalfields and that Middle Damudas may safely be taken as the correct term for beds equivalent to those mentioned.

Middle Damudas.

As already stated, it seems best to adopt the term Middle Damudas for those strata above the Barakar and below the Raniganj series throughout the Damodar valley. In the case of the Raniganj and Jharia fields, local conditions have permitted the use of these terms Ironstone Shales and Barren Measures for more or less equivalent strata, but the particulars of each are now well enough known to need no explanation to fit either into the Middle Damudas. In the Karanpura field, a certain degree of revision seems necessary in order to differentiate between the Upper Damudas (Raniganj series) and Middle Damudas. Further west it will become more and more difficult not only to separate the Raniganj series from the Middle Damudas below, but also from the Panchets above. Dr. Dunn has been unable to find any representatives of the Middle Damudas in the Aurunga coalfield, and in the Hutar field the so called Mahadevas are shown as resting on Barakars.

Upper Gondwanas.

Mahadevas.

In the Raniganj coalfield, there are two areas of rocks younger than the Panchets. The first of these is in the eastern part of the coalfield where the Lower Gondwanas dip under them and are hidden from view. The age of the newer rocks has not been established, but it is possible that the upper part of the Durgapur beds are not Upper Gondwanas at all

[1] *Mem. Geol. Surv. Ind.*, LXI, p. 109, (1932), and LVIII, p. 54, (1931), respectively.

and may represent Tertiary (Miocene) beds.[1] As regards the second area which caps Panchet Hill, although no fossils have been found, the rocks are regarded as the equivalents of the Dubrajpur beds of the Rajmahal hills. If this is correct, they will be Upper Trias to Rhaetic in age and roughly correspond with the Pachmarhi sandstones or Lower Mahadevas of the Satpura region. No rocks younger than these basal Mahadevas are found in the Bokaro and Karanpura coalfields, where they also cap the highest hills of each tract within the coalfields. Their distribution shows that there is a hiatus between them and the rocks on which they lie. This is in agreement with the succession found in the Rajmahal hills where the Dubrajpur beds are Infra-trappean. It is not possible to say definitely whether the Rajmahal lavas with their associated Inter-trappean plant beds ever extended over the Mahadevas of the Damodar Valley coalfields. That this is possible is indicated by the presence of quartz geodic fragments in the laterite of the eastern parts of the Raniganj coalfield. Here it is found usually in association with the suspected Tertiary (Miocene) Durgapur beds.

Raniganj Coalfield.

(By E. R. Gee.)

Location and area.

The Raniganj Coalfield, the second largest producer of coal in India at the present time, constitutes the most easterly of the chain of coalfields, which roughly follow the Damodar valley, within the provinces of Bengal and Bihar and Orissa. Lying about 120 to 140 miles north-west of Calcutta, it is bounded on the north, west and south by the Archæans. To the east, alluvium and laterite cover the Gondwana strata, and in the absence of deep bore-holes through these superficial sediments, the eastern limit of the field is largely a matter of speculative opinion. The present *proved* limits of the field are, however, from longitude 86° 36′ in the extreme west to about longitude 87° 20′ in the east, the area of this tract of Gondwana rocks being about 600 square miles.

The Damodar river traverses the southern half of the coalfield in a general east-by-south direction. In the western part of the

[1] *Mem. Geol. Surv. Ind.*, LXI, p. 69, (1932).

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field it is joined by the Barakar river, which, flowing from the north, traverses this western portion of the area. The main line of the East Indian Railway runs east-to-west through the coalfield, whilst a network of branch lines diverge to the north and south, the latter linking up with the Bengal Nagpur Railway at Adra junction, about 16 miles south of the field.

Earliest reference : Sumner and Heatly.

The earliest official reference to the exploitation of coal in the Raniganj field (and, incidentally, in India) is contained in a memorial, dated 11th August, 1774, which was presented to Government by Messrs. S. G. Heatly and J. Sumner of the Bengal Civil Service.[1] As a result, mining was apparently commenced in 1775, at Aitura (Aytooreah), Chinakuri and Damulia.

D. H. Williams, 1845-46.

The first systematic geological survey of the field was, however, not carried out until the years 1845-46, when Mr. D. H. Williams, Geological Surveyor to the Honourable East India Company, visited the area; in 1850, his report, including a geological map, was published.[2]

W. T. Blanford and W. L. Wilson ; 1858-60.

In 1858-60, the Raniganj field was again surveyed, on the scale of one inch to one mile, by Messrs. W. T. Blanford and W. L. Wilson of the Geological Survey of India. Of the geological map and the report[3] (compiled by Blanford), which resulted from this survey, it would be difficult to speak too highly. Suffice to say, that for many years they formed a most useful guide to colliery development and a basis for future surveys.

H. Walker and R. R. Simpson ; 1908-10.

During the years 1908-10, a third geological survey was carried out by Mr. H. Walker of the Geological Survey of India and Mr. R. R. Simpson of the Department of Mines, on a scale of four inches to one mile. Subsequently, in 1913, Mr. Walker produced a short paper[4], dealing principally with the correlation of certain

[1] *Journ. Asiat. Soc. Beng.*, XI, Pt. 1, pp. 813-814, (1842).

[2] 'A Geological Report on the Damoodah valley', by D. H. Williams, Esq., late Geological Surveyor in the service of the East India Company. Printed by order of the Court of Directors, 1850. Subsequently reprinted in Calcutta, 1853.

[3] *Mem. Geol. Surv. Ind.*, III, Pt. 1, (1861).

[4] *Trans. Min. Geol. Inst. Ind.*, VII, Pt. 3, p. 226, (1913).

of the coal seams of the field, whilst a much larger work by Mr. Simpson,—a memoir entitled 'The Coalfields of India '[1]—includes a summary of the geology with particular reference to the coal seams.

During the field-seasons 1925 to 1928, the Raniganj field was again geologically surveyed by this department using new topographical maps of a similar scale of four inches to one mile, but of considerably greater accuracy. The party, under the superintendence of Dr. C. S. Fox, included the late Rao Bahadur S. Sethu Rama Rau, Mr. E. R. Gee and Rai Bahadur A. K. Banerji; in 1926 Mr. J. B. Auden also joined the coalfields party. The four inches to one mile geological maps, resulting from this survey, are now available to the public, as is also a reduced one inch to one mile map which is included in the memoir 'Geology and Coal Resources of the Raniganj Coalfield '[2] (written by Mr. E. R. Gee), which deals with this subject.

In the latter memoir, and in the one written by Mr. Simpson, is a list of references to the extensive literature on this coalfield.

Stratigraphy and general structure.

The complete stratigraphical succession represented in the Raniganj coalfield is as follows :—

Recent and Sub-Recent .	Alluvial and lateritic deposits.		
Upper Gondwanas .	Supra-Panchets (or Panchet Hill, etc.).		
	(?= Durgapur beds.)		
	(? *Unconformity.*)		
Lower Gondwanas .	Panchet series.		
	Damudas . .	Raniganj measures.	
		Ironstone Shales.	
		Barakar measures.	
	Talchir series.		
	(*Large unconformity.*)		
	(Archæans.)		

The following table gives a summarised description of the various stages of the Gondwana sediments of the Raniganj field, together with their characteristic fossils, and their respective maximum thickness. The latter agree fairly well with the thicknesses given by Dr. Blanford[3], but in the case of the Barakar and Raniganj measures, borings put down in more recent years have led to more precise figure.

[1] *Mem. Geol. Surv. Ind.*, XLI, Pt. 1, (1913).
[2] *Op. cit.*, LXI, (1932).
[3] *Op. cit.*, III, Pt. 1, p. 81, (1861).

Regarding the Durgapur beds of the south-eastern part of the field, Dr. Fox has suggested that they may be of Miocene or Post-Miocene age.

Gondwana succession of the Raniganj coalfield.

Stratigraphical division.		Description of beds.	Included fossils.	Maximum thickness in feet.
Supra-Panchets (of Panchet hill).		Coarse, red, yellow and grey sandstones and quartzose conglomerates, with bands of dark red shales.	Fragments of stems and fossil-wood.	? 1,000
Panchet series .		Coarse, yellow and grey, soft, micaceous, false-bedded sandstones, with thick red clays; khaki-green shales and sandstones at the base.	Plant remains (including several types distinct from the Damudas); *Glossopteris*, *Pecopteris*, *Schizoneura*: also reptilian and fish remains, *Estheria* (*Posidonia*).	2,000
Damudas.	(c) Raniganj measures.	Mainly fine and medium-textured, grey and greenish, false-bedded, felspathic sandstones, with shales and coal seams.	Plant remains including *Vertebraria*, *Trizygia*, *Glossopteris*, *Pecopteris*, *Schizoneura*, *Phyllotheca*, etc.	3,400
	(b) Ironstone Shales.	Black carbonaceous shales, with occasional sandy micaceous shales, and numerous bands of clay ironstone.	Plant remains abundant, though not well-preserved; *Glossopteris*, etc.	1,200
	(a) Barakar measures.	Coarse conglomerates, with white and grey sandstones, often false-bedded; shales and coal seams of variable character.	Plant remains including *Glossopteris*, *Gangamopteris*, *Vertebraria*, etc.	2,100
Talchir series .		Coarse sandstones, white or slightly variegated at the top, fine khaki-green and blue-green shales, with sandy shales and fine green sandstones, including undecomposed felspar; at the base is a boulder bed, including boulders up to 15 feet diameter.	Plants very rare, a few stems, seeds ?, etc.	900
			TOTAL .	10,600

General structure.

In general, the geological structure of the Raniganj field is of a comparatively simple type. Over the greater portion of the field the dip of the beds is in a southerly direction. The Talchirs are, therefore, exposed adjoining the northern boundary, and successively newer Gondwana horizons come in as the coalfield is traversed from north to south, the Raniganj and Panchet beds cropping out over wide areas of

the southern half of the coalfield. Except along certain limited tracts of the north-eastern edge of the field, the northern boundary of the basal Gondwanas and the metamorphics is a line of natural deposition, normally unconformable and irregular (the Barakars overlapping the Talchirs in the north-eastern end of the coalfield), and, at a subsequent date, further complicated by faulting.

The southern boundary.

Along the southern boundary of the coalfield, to the west of the Barakar river, various horizons of the Barakar measures crop out for a considerable distance against the metamorphics though occasional small outcrops of Talchir sediments are observed; but further east, where the area of Gondwana rocks widens considerably, the higher beds of the Gondwana succession cover large areas of the southern half of the field, and horizons ranging from the uppermost Raniganj measures up to the Supra-Panchets, are exposed adjoining the crystalline gneisses. In contract to the northern limit of the field, this southern boundary is represented by a well-defined fault. (see page 84).

Intrusive igneous rocks.

The Gondwanas of the Raniganj field, as of certain of the closely-associated Damodar Valley coalfields, are intersected by a number of intrusives. These include two distinct types :—

(*a*) basic, doleritic or basaltic dykes of regular habit.

(*b*) ultra-basic, mica-peridotite and lamprophyric dykes and sills, which show considerable variation in their modes of occurrence.

Dolerite and basaltic intrusions.

Of the dykes of the former type, which occur vertically disposed or occasionally inclined, traverse the Gondwana strata and the Archaeans alike, and are unaffected by the faulting of the coalfield, the Salma dyke is the most prominent. This intrusive traverses the eastern part of the field in a S. 15° to 20° E. direction, its width being about 150 feet. Other important dykes of similar type include, the Narsamuda dyke running N. 42° W. *via* Narsamuda Colliery; the Sitarampur dyke running from near Sitarampur station to the metamorphics near Debipur; and an important intrusion running N. N. E. through Charanpur Colliery. As a result of their limited occurrence, regular habit, and very slight detrimental effect on the coal seams, these dolerite intrusives present no great obstacles to mining in the Raniganj field.

Unlike the basic intrusives, the mica-peridotite and lamprophyric types are confined to the Gondwana beds and also appear to be intimately associated with certain of the faults of the area. They vary in habit from fairly regular dyke-intrusions to anastomosing sills which, on account of the fact that the coal seams have formed very favourable channels for their widespread intrusion, have played havoc with the coal in certain areas, converting it into a hard coke or semi-coke, known as *jhama*. Though occurring in greater abundance within the Lower Damudas, these intrusions are also widespread in the Raniganj measures of certain areas and continue as a number of narrow dykes in the overlying Panchet strata of the southern portion of the field. Up to the present, no intrusions of this type have been met with in the limited outcrops of the Supra-Panchet rocks of the southern boundary of the coalfield, neither was their presence noted among the Durgapur beds of the extreme eastern part of the Raniganj area. These complex intrusions have been proved to occur principally within the following areas:—

Mica-peridotite intrusives.

(*a*) The lower Barakar coal measures of the Barmundih, Alkusa, Itapora Sarshatali areas, of the northern parts of the coalfield.

(*b*) The middle Barakar coal measures of the Shampur, Chatabar, Patlabari areas west of the Barakar river; and the Bahira and Kapistha-Madanpur areas east of the Barakar.

(*c*) The upper Barakar coal measures of the Balltara-Kendua area just east of the Barakar river.

(*d*) The lower Raniganj coal measures of the Sanktoriya (Sanctoria), Sudi-Kanyapur, Jamuria and Majiara area.

(*e*) The middle Raniganj coal measures of the Majiara-Rana-Shripur area.

(*f*) The upper Raniganj coal measures of the Siarsol area, to the north of Raniganj.

Regarding the age of these intrusives; the doleritic and basaltic dykes have usually been correlated with the volcanic basalts of the Rajmahal hills, of an age not older than Lower Jurassic. Recently, however, Dr. Fox has pointed out that these Damodar Valley dolerites may well belong to the Deccan trap period of vulcanicity, indicating a probable middle Cretaceous age. As regards the ultra-basic intrusives, noting their intimate connection with the faulting of the area, and bearing in mind the fact that the major faults of the field also affect the Supra-Panchet strata (of suggested Rhaetic age), it is obvious that they must belong to a period not

Age of intrusions.

older than the Lias. The evidence of the Raniganj area at least indicates a sequence of events in the following order:—

(i) Earth-movements resulting in at least the major displacements of the Gondwana strata, followed very closely by,
(ii) the intrusion of the ultra-basic (mica-peridotite and lamprophyric) series, and
(iii) The intrusion of the dolerites, definitely subsequent to the faulting.

Structure : faults and folds.

That the area of Gondwana rocks that now constitutes the Raniganj coalfield was subjected to a phase of relatively steady subsidence, extending over a very long epoch, during late Palaeozoic and early Mesozoic times, is evidenced by the unbroken sequence of sediments of constant fresh-water, or estaurine type. There is, however, no reason to suggest that this area of gradual subsidence and accompanying sedimentation was limited by any tectonic structures—either rift-faults or pronounced folds—as has been previously suggested. On the contrary, there is little doubt that the present tract of Gondwanas, now included within the Raniganj coalfield, represents only a very small portion of the original area of Gondwana sedimentation and owes its preservation to the fact that it has been subsequently faulted down within the Archaean land-mass and has thus been protected against the forces of erosion and atmospheric weathering.

The principal dislocation is the main complex boundary-fault which, limiting the coalfield to the south and west, has caused the Gondwanas to subside within the Archaeans to a depth varying up to at least 9,000 feet in the vicinity of Panchet Hill. This southern fault is by no means a single unbroken displacement, but rather a series of large strike-faults running *en echelon*. With the exception of certain tracts along the middle portion of the field, affected by strike or oblique faults, the northern limit of the coalfield is, in contrast to the southern, one of natural deposition, representing the uneven Archaean land-surface that existed in early Gondwana times. As has been previously observed, the general inclination of the Gondwana strata of the Raniganj field is towards, or slightly oblique to, these main southern and south-western dislocations. As the faults are approached, however, the effects of these immense subsidences are seen; the older strata (topmost Raniganj measures) are in many cases brought up against the faults in the form of sharp synclinal and in the immediate

vicinity of the fracture dip at steep angles to the north-east and north.

In the extreme north-eastern part of the coalfield, the large oblique strike-fault following the Adjai river, with a downthrow to the north-east, has, in a manner similar to the above-described southern boundary fault, effected the preservation of the Trans-Adjai strip of Damuda sediments.

In addition to these main dislocations, there are a number of cross-faults, some of very considerable throw, others of only minor consequence, which complicate the northern boundary of the coalfield and in many cases continue southwards for a great distance within the higher Gondwana strata. Particularly in the case of certain of these northern cross-faults, the strata swing round markedly, almost parallel to the dislocations, so that the local structures include a succession of fractured monoclines following along the lines of the faults, with synclinals, pitching steeply southwards, in the adjoining areas.

Age of faults and folds.

Regarding the age of these displacements, although—from the evidence of the unconformity of the Panchet and Supra-Panchet rocks—it is possible that minor faulting and folding commenced in early Gondwana times, on the other hand it is certain that the major displacements, affecting as they do the Lower Gondwanas and Supra-Panchets alike, took place at a later date, probably during Jurassic times.

Correlation of the coal measures.

During the recent re-survey of the Raniganj field, a detailed correlation of the Barakar and of the Raniganj coal measures was effected. This correlation is summarised in the tables given below:

Analytical classification of coal seams.

The coal seams of the Raniganj field fall into two fairly well-marked groups, which correspond with the major geological classification of the measures into a lower (Barakar) and an upper (Raniganj) series. The characteristics of these two groups are as follows:—

I. Barakar coals.

(*a*) A relatively low percentage of moisture ranging in most instances from 1 to 3·30 per cent.

(*b*) A comparatively low percentage of volatiles, ranging in most cases from 21 to 30 per cent.

(*c*) A high proportion of fixed carbon ranging from about 52 to 64 per cent. ; a figure around 55 per cent. is often recorded.

(*d*) The better quality coals are excellent steam coals and exhibit marked tendencies to form a hard metallurgical coke.

II. Raniganj coals.

(*a*) A relatively high proportion of moisture ranging from about 3 to 10 per cent. though in the case of the Dishergarh seam from 1·35 to 3 per cent. is often recorded.

(*b*) In the case of the better quality seams, the percentage of volatiles is high normally ranging from 29 to as much as 38 per cent.

(*c*) With the exception of the Dishergarh and Sanctoria seams of the basal measures of the western part of the field, the coals either fail to cake at all or produce a very soft, porous coke. Most of the better quality coals are excellent gas-coals, and free-burning steam-coals.

These characteristics are exemplified in the following analyses, which are typical of the better quality coals of the field.

Coals of Barakar age.

Name of seam.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value.
	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Chanch-Begunia seam (Begunia Khas Colliery).	2·10	27·60	60·00	12·40	7,194
Ramnagar seam (Ramnagar Colliery).	2·0	27·4	55·20	15·40	..
Laikdih seam (bottom 17 feet) (Victoria Colliery).	1·40	26·00	62·60	11·40	7,632
Kasta seam (bottom 12 feet) (Poriarpur Colliery).	2·66	32·05	57·00	10·95	7,318
Damagaria seam (bottom portion) (Damagaria Colliery).	1·24	23·00	62·00	15·00	7,149

...ari-Bahira (Borrea) area.	Alkusha-Modanpur Itapora area.	Gourangdi-Churulia area.	Trans-Adjai area.
...posed, as a result of strike-fault-... Bahira (Borrea).		Sandstones and shales. ? Upper 4-foot SEAM of Kantapahari and Kapistha.	(Upper part of measures unproved.)
...feet (proved beneath Ironstone ...th of Bahira). ...a result of strike-faulting South ...rrea).	Coal seams unexposed, outcrops relatively poor.	Sandstones and shales (unproved).	Sandstones and shales about 350 feet, including several thin seams of COAL near the base.
... of old inclines to dip of main ...p-workings). ... seams. { Coal 6 to 8 feet. Sandstones 5 to 10 feet. Coal 2 to 4 ft. 6 ins. Sandstone 15 to 25 feet. Coal 30 to 34 feet. }		UPPER KANTAPAHARI-JAMGRAM seam (19 to 27 feet).	
...shales (95 feet approx.).		Massive sandstones and shales (200 to 220 feet).	Sandstones and shales (100 to 150 feet). Mainly thick grey shales (180 feet).
... seam — Salanpur 'D' seam (5 feet). Strata 40 feet. ... seam — Salanpur 'C' seam (18 feet).		MAIN GOURANGDI-JAMGRAM CHURULIA seam (20 to 30 feet).	KASTA seam (28 to 40 feet).
...sandstones with shales and fire-... ...ral thin COAL seams (350 to	Grits, sandstones and shales with fireclay (250 feet approx.).		Grits, massive sandstones, and shales, with bands of fireclay and at least one seam of COAL and shaly COAL.
...' seam (7 to 10 feet). ...eet. ...' seam (100 to 125 feet).	THICK COAL and shale seam of Alkusha, becoming more shaly to the east (80 to 100 feet).	Seam of shaly COAL and shale (40 feet approx.).	Basal sandstones pebbly.
...ox.).	Conglomeratic sandstones (200 to 250 feet).	Basal conglomerates.	
	Thin seam of COAL (2 to 4 feet).		
	Soft sandstone with some pebbles.		

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field, those regarded as of 'superior quality' are included in at least the majority of analyses within either the selected grade or Grade I of the Grading Board's classification. Those of class (3), on the other hand, often fall below the specification required for Grade I.

Coal already exploited or lost.

The total amount of coal exploited within the Raniganj field since the commencement of mining is estimated at 270 million tons. Regarding the apportioning of this total amount between the three different classes under which the reserves are estimated, the following proportions are suggested :—

1. Caking coal 30 per cent.=81 millions of tons.
2. Non-caking coal of superior quality 40 per cent.=108 millions of tons.
3. Coal of inferior quality 30 per cent.=81 millions of tons.

Reserves of coal.

Allowing for those areas which are markedly affected by complex faulting or igneous intrusions, deducting five per cent. from the total quantity of coal that existed prior to the commencement of mining in order to provide for the loss entailed by those igneous intrusions which are seen scattered within the measures, and including also an arbitrary loss of 50 per cent. of the total coal already raised (to cover losses due to poor methods of extraction, fires, collapses, etc.), the following reserves are calculated :—

Caking coal of superior quality.

Name of seam.	Original quantity (expressed in tons).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Ramnagar	12,066,000	22,227,000
Laikdih	18,343,000	31,298,000
Begunia	12,193,000	26,672,000
Sanctoria	13,336,000	13,336,000
Dishergarh	106,853,000	237,372,000
Original total	162,791,000	330,905,000
Amount already exploited	81,000,000	81,000,000
Present reserves	81,791,000	249,905,000

Non-caking coal of superior quality.

Name of seam.	Original quantity (expressed in tons).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Damagaria-Salanpur 'A'	62,006,000	99,156,000
Gourangdi-Kasta	24,475,000	43,020,000
Shampur '5'-Laikdih-Bahira '3'	43,156,000	113,736,000
Top Fotka-Chanch-Begunia	27,294,000	57,078,000
Sanctoria-Poniati	170,335,000	324,379,000
Dishergarh	29,060,000	152,170,000
Samla	131,582,000	131,582,000
Raghunathbati	8,764,000	8,764,000
Jambad-Bowlah	132,090,000	132,090,000
Nega-Raniganj-Lower Kajora	261,766,000	307,490,000
Ghusick-Siarsol-Upper Kajora	172,225,000	300,374,000
Satpukhuriya	8,891,000	8,891,000
Original total	1,071,644,000	1,678,730,000
Amount already exploited	108,000,000	108,000,000
Present reserves	963,644,000	1,570,730,000

Coal of inferior quality.

—	Original quantity (expressed in tons).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Original total	4,712,142,000	6,940,291,000
Amount already exploited	81,000,000	81,000,000
Present reserves	4,631,142,000	6,859,291,000

Total reserves of coal of all kinds.

—	Original quantity (expressed in tons).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Caking coal of superior quality	162,791,000	330,905,000
Non-caking coal of superior quality . . .	1,071,644,000	1,678,730,000
Coal of inferior quality	4,712,142,000	6,940,291,000
Original total	5,946,577,000	8,949,926,000
Present reserves	5,676,577,000	8,679,926,000

Production of coal (by C. S. Fox).[1]

The coalfield was brought to notice in 1774. The first reference relating to the annual production refers to the years 1815 to 1823 when 400 tons a year appear to have been raised. The Coal Committee for 1845 give some figures for several years with which Mr. Homfray's returns for the same time do not agree. The first accurate statement of accounts begins with 1858 when Dr. T. Oldham collected the data then available. It is unfortunate that for the greater part of the period since 1858 to 1898 no separate returns are available for the Raniganj field alone. Mr. E. R. Gee has computed the total output of the field since 1815 and up to 1929 as roughly 180 million tons.

[1] The several references relating to old statistics of the output of coal from the Raniganj coalfield are given below :—

1. Herbert, J. H., *Asiatic Researches*, XVI, pp. 397-408 (for 1815-23 period).
2. Coal Committee Report for 1845, p. 150, (1846).
3. Blanford, W. T., *Mem. Geol. Surv. Ind.*, III, p. 183, (1861) (for the Raniganj coal-field).
4. Oldham, T., *ibid. Mineral Statistics*, I, Coal, (1861).
5. *Op. cit.*, VII, Art. 2, pp. 131-150, (1869).
6. Ball, V., *Man. Geol. Ind.*, Pt. III, Eco. Geol., pp. 594-595, (1881).
7. Numerous publications since including *Imp. Inst. Hd.-Bk.*, *Com. Prod.*, *Indian Section*, No. 9, Indian Coal, pp. 22-27, (1893); Financial and Commercial Statistics of British India, p. 37, (1904); Statistics of Mineral Production in India, 1900 to 1903 ; Review of Mineral Production for 1897 (David Hooper) (1898); *ibid*, for 1894, 1895 and 1896 (George Watt) (1895, 1896 and 1897). Since 1898 the returns have been published in the *Records of the Geological Survey of India*, annually and in quinquennial periods after 1898-1903, thus 1904-1908, 1909-1913, 1914-1918, 1919-1923, 1924-1928 and 1929-1933. The information was brought up to date for the Raniganj coalfield as far as was then desired, by Mr. E. R. Gee [*Mem. Geol. Surv. Ind.*, LXI, p. 278 *et seq.*, (1932)].

The production for Raniganj as against that of Bengal and all-India for the period 1858-1868 are given below :—

Year.	Indian total.	For Bengal only.	Raniganj field.[1]
	Tons.	Tons.	Tons.
1858	226,306	226,306	216,930
1859	365,844	365,844	328,666
1860	370,481	370,481	314,326
1861	286,678	285,901	271,606
1862	317,438	316,961	300,853
1863	349,327	349,063	417,806
1864	332,212	331,708	331,708
1865	324,567	323,556	396,989
1866	397,890	396,254	396,263
1867	435,587	435,078	437,282
1868	497,035	494,522	483,784

The above figures have been calculated from maunds which are taken as 27·23 maunds to the ton (avoir.)[1].

Dr. V. Ball gives the coal carried by the E. I. Ry. as the only data regarding the output of the Raniganj and even Bengal coal-fields between 1868 and 1880 as below [2]:—

Year.	Coal carried by E. I. Ry.	Production from Raniganj field.
	Tons.	Tons.
1868	459,408	483,784
1869	552,379	....
1870	508,588	....

[1] The corresponding figures for 1857-58 to 1868-69 are given by Dr. Ball (Man. III, p. 63) but evidently calculated at 27·25 maunds to the ton.

[2] Manual of Geology of India, Pt. III, Economic Geology, p. 592, (1881).

Year.	Coal carried by E. I. Ry.	Production from Raniganj field.
	Tons.	Tons.
1871	415,800	....
1872	434,880	....
1873	552,379	Dr. Ball gives 369,431 tons for 1870-71, 284,623 tons for 1871-72 ; an average of 467,924 tons annually for 1875-76, 1876-77 and 1877-78 ; 523,097 tons for 1878-79 and 469,699 tons for 1879-1880. All these are evidently based on 27·25 mds. to the ton.
1874	689,561	
1875	629,914	
1876	643,025	
1877	813,066	
1878	879,187	....
1879	902,949	553,829
1880	907,494	....

As the E. I. Ry. did not tap the Giridih coalfield till 1871, most of the coal carried in 1868 was from the Raniganj coalfield. And as Dr. Ball himself shows (*op. cit.*, p. 595) that the output from Raniganj (Burdwan and Manbhum) in 1879 was 553,829 tons it is evident that Giridih and perhaps other fields were supplying coal then. Giridih produced 336,326 tons in that year. The production for Bengal was 957,243 tons in 1878, 891,047 tons in 1879, and 988,565 tons in 1880. These are all the data we have for estimating the production from the Raniganj field in the period 1869-1880. In fact from 1880 to 1889, there are evidently no procurable details for the Raniganj field alone, and estimates from 1878 to 1897 must be ascertained from the figures given below :—

Year.	Production from Bengal.	Production from Raniganj.
	Tons.	Tons.
1878	957,243	....
1879	891,047	553,829
1880	988,565	....
1881	930,203	....

Year.	Production from Bengal.	Production from Raniganj.
	Tons.	Tons.
1882	1,038,872	....
1883	1,200,957	....
1884	1,257,392	....
1885	1,123,700	....
1886	1,186,802	....
1887	1,319,090	....
1888	1,380,594	....
1889	1,541,356	....
1890	1,626,245	1,082,136
1891	1,747,122	....
1892	1,920,050	....
1893	1,902,866	....
1894	2,035,934	....
1895	2,716,155	....
1896	3,037,920	2,369,265
1897	3,142,497	2,144,161[1]

The production of coal from the Raniganj coalfield is shown separately for the period since 1898 to date in the table below :—

Year.	Total Raniganj.	Total Gondwana.	Total India.
	Tons.	Tons.	Tons.
1898	2,216,441	4,301,147	4,608,196
1899	2,396,742	4,757,626	5,093,260
1900	2,552,414	5,785,114	6,118,692

[1] The output from the newly opened Jharia coalfield is excluded from the Raniganj total (2,477,597 less 333,436).

Year.	Total Raniganj.	Total Gondwana.	Total India.
	Tons.	Tons.	Tons.
1901	2,841,699	6,264,681	6,635,727
1902	3,042,223	7,083,179	7,424,480
1903	3,066,720	7,076,376	7,438,386
1904	3,350,257	7,808,027	8,216,706
1905	3,262,536	7,993,363	8,417,739
1906	3,650,563	9,348,884	9,783,250
1907	3,981,659	10,720,245	11,147,339
1908	4,221,781	12,373,018	12,769,635
1909	4,034,812	11,463,299	11,870,064
1910	4,212,606	11,635,540	12,047,413
1911	4,311,956	12,329,458	12,715,534
1912	4,944,268	14,298,083	14,706,339
1913	5,327,248	15,814,304	16,208,009
1914	4,946,295	16,039,261	16,464,263
1915	5,484,596	16,673,237	17,103,932
1916	5,535,307	16,863,466	17,254,309
1917	5,376,022	17,814,524	18,212,918
1918	6,368,519	20,322,892	20,722,493
1919	6,815,126	22,238,802	22,628,037
1920	4,997,679	17,526,444	17,962,214
1921	5,211,855	18,844,092	19,302,947
1922	5,203,214	18,520,513	19,010,986
1923	5,557,424	19,217,176	19,656,883
1924	6,035,347	20,696,338	21,174,284
1925	5,729,686	20,447,898	20,904,377
1926	6,124,884	20,583,202	20,999,167

Year.	Total Raniganj.	Total Gondwana.	Total India.
	Tons.	Tons.	Tons.
1927	6,472,036	21,664,488	22,082,336
1928	6,460,490	22,153,314	22,542,872
1929	6,828,053	23,001,586	23,418,734
1930	7,218,691	23,342,372	23,803,048
1931	6,530,713	21,331,872	21,716,435
1932	6,419,007	19,814,524	20,153,387
1933	6,265,703	19,456,261	19,789,163

Concluding remarks.[1]

Reviewing the coal reserves of the Raniganj field (as included within the above tables), it is observed that the quantity of coal that *without admixture* yields a coke of metallurgical quality, and which is limited to the Ramnagar and portions of the Laikdih seams, is decidedly small. Adding to this total, however, those reserves of good quality coal which, when mixed with a strongly-caking low-volatile coal, have proved to yield a valuable hard coke, the quantity—derived largely from the Dishergarh seam—becomes immensely larger and of very appreciable importance, reaching a total of nearly 82 million and 250 million tons within depths of 1,000 and 2,000 feet respectively.

The present annual output of the coalfield is in the nature of 6¼ million tons, that is, about 30 per cent. of India's total.

Deposits of iron-ore, fire-clay, etc.

In addition to the reserves of coal, the Raniganj field includes, within the Ironstone Shale measures, large deposits of clay-ironstone which for a number of years was used—mixed with high grade ore from near Tatanagar—in the blast-furnaces at Kulti.

Good quality fire-clays, though of somewhat limited occurrence, are also obtained from the Barakar measures, whilst a small deposit of an impure limestone is met with along the Lower Panchet rocks near Panchet Hill. In addition, large quantities of river

[1] These remarks and those on iron-ore, etc., are written by Mr. E. R. Gee.—Ed.

sand are available within the Barakar and the Damodar rivers, inside the limits of the coalfield.

Trans-Adjai Coalfield.

It is sometimes convenient to refer to that portion of the Raniganj coalfield north of the Adjai river from Pariarpur (23° 50′ : 87° 3′) eastwards to Pajera (23° 45′ : 87° 19′) as the Trans-Adjai coalfield. This strip, showing only the Barakar series, with the thick coal of Kasta and Paharpur, and the assumed position of the boundary of the Ironstone Shales or Middle Damudas, is given on the map accompanying Mr. Gee's memoir. The coal and strata are discussed in his memoir on pages 177 to 185.

Eastern Extension of Raniganj Coalfield.

The information dealing with the Rajmahal hills and the outlier of Damudas in the Tangsuli basin north-west of Suri provided evidence for the belief in the connexion of the Gondwanas of the north with those of Raniganj. And the manner in which the Lower Gondwanas in the eastern end of the Raniganj field dip under younger formations, which in turn are covered by alluvium, supports the opinion that the coal measures strata continue beneath for some distance. It was even thought that these coal measures might be within 2,000 feet of the surface in the valley of the Adjai river as far as north of Burdwan, but on this point no published information is yet available. It has been shown that an eastward extension of the Raniganj coalfield does occur, but whether the seams will be unworkable, owing to the thickness of the overlying strata, cannot be answered without boring. The Durgapur, or Kalipur, boring by the East Indian Railway indicates a great thickness of unprofitable strata to be pierced before the coal measures will be met with in the south-eastern area of the field.

Another question which arises is the possibility of finding coal to the south of the Raniganj coalfield, *i.e.*, on the upthrow side of the south boundary fault. There is little doubt that the Gondwana deposits must have extended further south than the limit of this fault. As gneissic rocks are seen in that direction, and the throw of the fault is known to be upwards of 10,000 feet, it

is presumed that all the sedimentary deposits have been long since removed by denudation. It must, however, always be regarded as possible that Barakar coal measures may be present, but if they are, they have escaped our notice and can be present only in small outliers.

Supposed Midnapore Coal.

A supposed discovery of coal at Midnapore[1] fifty years' ago proved to be a hoax.

[1] *Rec. Geol. Surv. Ind.*, XV, footnote, p. 210, (1882).

CHAPTER 7.

COALFIELDS OF BIHAR—*contd.*

DAMODAR VALLEY COALFIELDS—*contd.*

Jharia Coalfield.

Although the Raniganj coalfield was opened in 1775, and the Bokaro and Karanpura coalfields were under examination as late as 1848, nevertheless the Jharia coalfield remained undiscovered for almost another ten years. Dr. David Smith crossed the area in 1856 southward from the Fitcooree bungalow (now in ruins about mile 175¾ on the Grand Trunk road at latitude 23° 51′ 19″: longitude 86° 24′ 34″), north of Dhanbad. On his way to Jharia, he would have crossed the Talchirs and a wide exposure of Barakar sandstones, including the well-marked 'burnt-outcrops' of at least three important seams, and yet he mentions no occurrence of coal. However, coal was found soon after, as it is known that the area was specially examined for a Calcutta firm in 1858 by Dr. Emil Stöhr. His report was not made public, and the existence of coal was first publicly proved by the samples of coal obtained in 1862 by Major J. L. Sherwell. However, Dr. Emil Stöhr's discoveries appear to have been made known to the Geological Survey of India before Major Sherwell's reports were made, and, as soon as topographical maps were available, the Jharia coalfield was surveyed by Mr. T. W. H. Hughes.[1]

Location of field.

The Jharia coalfield is situated immediately south and south-east of Parasnath Hill, between 23° 37′ and 23° 52′ north latitude and 86° 6′ and 86° 30′ east longitude, in the Chota Nagpur division of Bihar and Orissa. It lies about 170 miles W.N.W. of Calcutta and is in railway communication with it by the East Indian and Bengal-Nagpur Railways. These lines also give an outlet to the Madras coast, the Central Provinces, and to the Ganges valley of the north and north-western India. The Damodar river passes through the southern part of the field but is not navigable. It provides a source of supply of sand for stowing purposes to those collieries which have adopted this valuable method of working their seams.

[1] 1865-66, see *Mem. Geol. Surv. Ind.*, V, Pt. 3, (1866).

The drainage of the field is largely from the north to the Damodar. The water-supply for collieries is now chiefly secured from the Rajdaha (near Topchanchi) reservoir at the south-eastern toe of Parasnath, north of the Grand Trunk road. Finally the office of the Chief Inspector of Mines in India is situated at Dhanbad at the north-east corner of the coalfield (see Plate 13).

Area of Gondwana formations.

The total area of Gondwana rocks exposed in the Jharia coalfields is about 175 square miles; the area occupied by the outcrop of the Barakar series is roughly 84 square miles; and the Raniganj series cover an area of approximately 21 square miles. These estimates include the two square miles of Talchir and Barakar rocks which occur at Chandrapura (23° 45′ : 86° 7′) on the Bokaro (west) side of the field. These measurement will show that the Jharia coalfield is smaller in extent than the Bokaro coalfield, and of course much smaller than the Karanpura or Raniganj coalfields.

Previous observers.

As already stated, the Jharia coalfield was privately explored in 1858, but details are not available. Mr. Hughes made the first complete geological investigation in 1865-66 and submitted a detailed report on his work. No development occurred until after 1890, when Mr. T. H. Ward made a further examination on behalf of the East Indian Railway with the assistance of Mr. Hughes' report and geological map.[1] In 1901, on behalf of the Weightman Committee, the area was again examined by Mr. G. A. Stonier[2], then attached to the Geological Survey of India. Neither Mr. Ward nor Mr. Stonier claim to have made a geological survey of the field and both utilised Mr. Hughes' map; they revised the older map and published new ones with additional particulars. In 1912 the Mining and Geological Institute of India appointed a committee to revise the geological map of the Jharia coalfield. The coal seams were demarcated by a surveyor appointed by the committee working mainly under the supervision of Mr. R. R. Simpson, and in 1917 the geological boundaries of the field were revised by Dr. G. de P. Cotter. The map was published in 1917 by the Institute in eight sheets on the scale of four inches to the mile. These sheets show the outcrops of the coal seams, the positions of

[1] *Rec. Geol. Surv. Ind.*, XXV, pp. 110-113, (1892).

[2] *Genl. Rept., Geol. Surv. Ind.*, for 1901-02, pp. 14-17; see also Suppl. to *Coll. Guard.*, (Sept. 16, 1904).

faults and dykes and other details, and have proved their value over and over again since they were first published by the Mining and Geological Institute of India in 1917; and the mining community owe Mr. Simpson a debt of gratitude for the completion of this work.

Latest geological survey.

In 1923 the Indian Tariff Board desired that the reserves of coking coal in the Jharia and Raniganj coalfields should be accurately ascertained. Sir Edwin Pascoe, Director of the Geological Survey of India, succeeded in having these two fields topographically re-surveyed and as soon as the new maps, on a scale of four inches to the mile, were ready, he instructed me to carry out the geological survey of both areas in detail. The Jharia coalfield was completed in the seasons 1926-28, and the memoir and four-inch maps were on sale by 1930. Those who desire fuller information on this field may therefore consult these maps and the latest memoir on the Jharia coalfield.[1] During the re-survey of the Jharia field, it was found useful to hold excursions of the Mining and Geological Institute in certain areas, where an agreement of opinion among the members was necessary in connexion with the recognition of definite points of geology and of the horizons of particular coal seams.

Geological structure.

The Gondwanas of the Jharia coalfield, consisting only of the Damudas and Talchirs, lie abruptly on gneissic rocks of Archaean age. The southern boundary of the coalfield is strongly faulted, with the gneisses showing to the south. All the Gondwana strata—Talchirs, Barakars, Barren Measures and the Raniganj series—dip inwards from the successive outcrops of the beds which form the field. Although the area is not semi-circular, but rather sickle-shaped, it is roughly 12 miles across the middle from the fault northwards, and 24 miles from east to west. Both in the east, about Pathardih, and in the west, near Dugda, there are irregularities suggestive of compression on a line between these places. A *horst* of gneisses occurs within the boundaries of the field near Pathardih, and the beds west of Dugda show evidences best explained by overthrusting. The axial line is parallel to, and north of, the southern boundary fault, *i.e.*, along an E. S. E. to W. N. W. line. The deepest part of

[1] See *Mem. Geol. Surv. Ind.*, LVI, (1930).

the field appears to be in the basin south of Mahuda station (B.-N. Railway) and in this area the inward dips converge from the beds north of the line of compression referred to. Around the Pathardih *horst* and west along the southern boundary fault, the strata are more steeply inclined and evidently more disturbed than elsewhere (excepting the believed overthrusting west of Dugda).

Faults and dykes.

There are several strike faults in the field and many of these are clearly 'sag' faults. They begin suddenly, increase in a mile or so to a considerable throw and when traced further are found to die out. Such faults are common in the north and central parts of the field. They are normal tensional faults, evidently related to those forming the southern boundary of the field. There are a few cross faults and some which are oblique to the run of the beds. At Dumra, where an inlier of gneisses occurs, it is seen that the faults of the coal-field become continuous with the quartz-reefs in the gneisses; moreover it seems certain that many of the quartz-reefs seen along the Grand Trunk road are really fault lines, which have become veins in which quartz has been deposited. A careful search has failed to discover any gold or metalliferous minerals in these quartz-reefs. The sills and dykes of mica-peridotite and dolerite and the natural coke (*jhama*) produced by these intrusions in the coal seams, are dealt with fully in my memoir.[1]

Stratigraphical geology: Talchir series.

As previously stated, there are in this field no strata younger than the Damudas, as no representatives of the Panchet series occur. The Damudas are seen to be clearly separable from the underlying Talchirs which are very well exposed in the north-western and western part of the field. Taken by themselves, the Talchirs of the Jamunia and other exposures do not give evidence of an Ice Age, as might at first be expected; but a search amongst the boulders of the boulder bed and a study of its matrix will lead to the conclusion that the various pebbles (including those clearly 'scratched'), and the sandy-clay matrix, must represent re-sorted moraine material. The Talchir boulder bed, about 50 feet thick and near the base of the series, provides but a small part of the total thickness of the Talchirs, which are quite 800 feet thick. The overlying beds are seen to consist of argillaceous sandstones, arenaceous (trappoid) buff-coloured clays, dark greenish shales with

[1] *Mem. Geol. Surv. Ind.*, LVI, pp. 113-146, (1930).

calcareous nodules, and greenish-buff splintery (needle) shales. These needle-shales are the *type* rocks of the Talchirs throughout Peninsular India, if found in association with the boulder bed. What is thought to be a 'glacial pavement' occurs north of hill 730, north of Suranga (23° 42′: 86° 27′ 45″—see sheet No. 7 of the four-inch sheets of the Jharia coalfield). No fossils were found in the Talchirs in this coalfield. As the beds are traced from west to east along the north of the field there is an overlap of the Damudas over the Talchirs on to the gneisses.

Damudas ; Barakars, Barren Measures, and Raniganj series.

The Damudas of the Jharia coalfield are roughly 6,000 feet thick in any assembled section. They are, as in the Raniganj field, separable into an upper and lower coal measures (with several workable seams of coal in each), and a middle series without workable coal seams. Plant fossils—chiefly *Glossopteris* leaves, *Vertebraria indica*, *Schizoneura* stems and leaves, and silicified fossil wood (with stems of wood replaced by siderite encrusted with a cortical band of bright coal)—are often met with in the coal measures and barren beds. So far no animal remains of any kind have been found in any of these strata.

From my detailed work in the Jharia coalfield and my knowledge of the Damuda rocks in the Raniganj coalfield, and in consultation with my colleague Mr. Gee, it has been possible to recognise the following subdivisions, of the Damudas in both areas :—

Blanford's classification.	Gee's subdivisions in Raniganj coalfield.		Fox's classification of Damudas in the Jharia coalfield.	
Raniganj series, 5,000 feet.	Raniganj series (8,300 feet).	Kumarpur sandstones Nituria coal measures Hijuli sandstones Sitarampur coal measures Ethora sandstones (600 feet)	Lohpiti sandstones . Telmucha coal measures Jamdiha sandstones . Murulidih coal measures	Raniganj series (1,840 feet.)
Ironstone Shales, 1,400 feet.	Ironstone Shales (1,200 feet).	Ironstone Shales of Kulti	Mahuda sandstones (600 feet). Hariharpur carbonaceous shales Petia sandstones . . Shibbabudih shales .	Barren Measures (2,080 feet.)
Barakar series, 2,000 feet.	Barakar series (2,100 feet.).	Begunia sandstones Begunia shales . Begunia seam[1] . Laikdih seam, etc. Damagaria seam	No. XVIII seam (Sitanala ?), etc. to No. I seam (Muraidih)	Barakar series (2,000 feet.)

[1] It is possible that the Begunia seam is the representative of a seam above No. XVIII of the Jharia coalfield. Similarly, the Damagaria seam is probably the representative of a seam higher in the succession than No. I of Muraidih. The Barakar stage is at its maximum development in the Jharia coalfield and appears practically to die out as a coal-bearing formation in the eastern area of the Raniganj coalfield.

It will be seen that I have a tripartite arrangement of series of equal thickness, the Middle Damuda division counting from the top workable coal seam of the Barakars (Lower Damudas) to the bottom workable coal seam of the Raniganj series (Upper Damudas). This is, to some extent, artificial as thin coal seams are not entirely absent in the Barren or middle measures, but it is a convenient arrangement for present day economic considerations. In any case the term Ironstone Shales would prove wrong in the Jharia area, as thin beds of sideritic shales, which weather into limonite with small nodules of *kankar* at their outcrops, are found in the Barakar series, and similar cases are rare among the beds of the Barren Measures.

Karharbari stage.

No detailed collections of plant fossils have been studied from the basal horizons of the Jharia coalfield, but, from the little we know, there seem to be no grounds for believing that the flora of the lower coal seams of the Karharbari (Giridih) coalfield is present in the Jharia area. On the other hand, it cannot be said that the coal of the Lower Karharbari seam is characteristically different from the coal of seams in the Lower Barakars of Jharia. I have very similar (dull, banded) coal specimens from seams near Chandore, although the quality is not so good and their volatile matter is less than in the typical Giridih coal from the lower Karharbari seam.[1]

Barakar (Coal Measures) series.

In discussing these beds, which are perhaps the most important coal measures strata in India, it was found convenient to divide them as below :—

Name of stage.	Coal seams.
4. Phularitanr stage with seams of Jorapokhar and Bhagaband.	Top XVIII, XVII and XVI.
3. Barari stage with seams of Jagta, Jialgara and Bhaunra.	XV, XIV-A, XIV and XIII.
2. Nardkarki stage with seams of Garoira and Tisra.	XII and XI, X, IX and VIII.
1. Golakadih stage with seams of Muraidih and Dhaunsar.	VII, VI, V, IV and III to base.

The section where these seams are recognised is north to south from Muraidih, through Maheshpur to Nawagarh, though even here all the seams are not included, as it was necessary to use the numbers adopted by Mr. T. H. Ward, to alter which would lead to confusion. In other parts of the field it was found that many

[1] *Rec. Geol. Surv. Ind.*, XI, p. 146, (1878).

of the lower and some of the upper seams either disappeared, split, or joined the seam above or below; or that new seams appeared. Thus it was found necessary to add the letter A or B (where two occurred) to that of the next known seam below.

Quality of coals.

The seams of the lower stages (1 and 2) are, as regards good quality caking coals, of less importance than those of the upper (3 and 4) stages. This will be best shown by the following analyses taken from pages 183-190 of the memoir of the geology of the Jharia coalfield (1930).[1]

Golakadih stage coals.

Colliery and seam.	Moisture.	Ash.[2]	Volatile matter.[2]	Fixed carbon.[2]	Calories.[2]
	Per cent.	Per cent.	Per cent.	Per cent.	
Behaldih East, V to VII .	1·02	20·95	15·15	63·90	6,607
North Matiagara, V/VI .	0·65	17·80	14·20	68·00	7,141
Isabella, V/VI . . .	0·95	14·75	16·80	68·45	7,257
Dhaunsar, V/VI . .	1·00	21·13	17·30	61·57	6,579

Nardkarki coals.

Colliery and seam.	Moisture.	Ash.[2]	Volatile matter.[2]	Fixed carbon.[2]	Calories.[2]
Gareira, top X . . .	1·01	14·90	19·50	65·60	7,276
" bottom X . .	0·94	17·20	20·80	62·00	7,019
Dheriajoba, X . .	1·00	18·60	19·00	62·40	6,809
Golakadih, X . . .	1·22	16·85	21·25	61·90	7,072
Kujama, X . . .	1·20	20·40	20·20	59·40	6,681
Katras, XI . . .	1·08	14·88	20·65	64·47	7,291
Kenwadih, XI . .	0·85	18·00	18·50	63·50	6,904
Lodna, XI/XII . .	1·40	15·90	22·50	61·60	7,104
South Tisra, XI/XII .	1·00	17·70	22·10	60·20	6,903
Chetudih, XII . .	0·90	17·40	19·80	62·80	7,004
Lewabaid, XII . .	0·80	13·50	18·40	68·10	7,376

[1] In the Jharia coalfield memoir, the terms Bhagaband, Jialgara, Gareira and Muraidih were also used as stage names in place of Phularitanr, Barari, Nardkarki and Golakadih, respectively, but the latter set are officially correct.

[2] All these are on a moisture free basis.

Barari stage.

Colliery and seam.	Moisture.	Ash.[1]	Volatile matter.[1]	Fixed carbon.[1]	Calories.[1]
	Per cent.	Per cent.	Per cent.	Per cent.	
Angrapatra, XIII . .	0·81	14·85	23·28	61·87	7,215
Bansjora, XIII . .	0·80	12·40	21·20	66·40	7,403
Barari, XIII . . .	1·07	13·20	24·95	61·85	7,338
Mudidih, XIV . . .	1·05	13·20	21·20	65·60	7,469
Gopalichak, XIV . .	0·68	13·65	21·65	64·70	7,437
Bhalgora, XIV . .	1·08	15·02	24·33	60·65	7,185
Standard, XIV-A . .	1·30	10·40	24·90	64·70	7,885
Bagdigi, XIV-A . .	1·10	7·90	26·35	65·75	7,737
Bhulanbarari, XV . .	2·20	12·05	25·45	62·50	7,432
Lodna (lower XV) . .	1·24	13·24	22·10	64·66	7,693
Barari (upper XV) . .	1·98	10·40	20·80	68·80	7,623
New Tentulia, XV . .	1·08	13·30	18·52	68·18	7,176
Katras, XV-A . . .	0·65	22·60	17·80	59·60	6,735

Phularitanr stage.

Colliery and seam.	Moisture.	Ash.[1]	Volatile matter.[1]	Fixed carbon.[1]	Calories.[1]
South Baliari, XVI . .	1·64	12·40	27·50	60·10	7,459
Bhulanbarari, XVI . .	2·10	23·00	24·35	52·65	6,410
Bhagaband, XVII . .	1·60	13·20	27·20	59·60	7,269
Jamadoba, XVII . .	1·70	11·00	26·70	62·30	7,517
Sitanala, XVII . .	1·93	9·22	29·47	61·31	7,492
Baliari, XVII-A . .	1·68	9·85	26·85	63·30	7,634
Amlabad (bottom XVIII)	1·50	13·77	27·86	58·37	7,210
Amlabad (top XVIII) .	1·21	11·25	27·05	61·70	7,471
Jamadoba (12′ 8″, XVIII).	1·87	14·75	27·98	57·27	7,059
C. Dharmaband, XVIII .	1·80	10·40	24·60	65·00	7,608

[1] All these are on a moisture free basis.

L 2

All these analyses of the Barakar coals from the Jharia seams are taken from the results of the Indian Coal Grading Board, and all belong to the low volatile type of coals. Many of the coals are clearly of excellent quality Nos. XIV, XIV-A, XV, XVII and XVIII seams being amongst the best steam and caking coals obtainable in India.

Raniganj (Coal measure) series.

It has already been stated that no workable coal seams have been recognised in the Barren Measures in the Jharia coalfield. The numbering of the seams south of the Pathardih gneissic 'horst' cannot be claimed as perfectly in accord with the numbering of the Barakar seams to the north, and for this reason some seams south of theDamodar river near Pathargarha (23° 39′: 86° 25′) may belong to XVIII, while that of Sitanala may really be lower than the horizon of XVII; but there are no such doubts with regard to the seams of the Raniganj series in the Jharia coalfield. These measures in Jharia are of far less importance than the Barakars as a coal-bearing formation. They are distinctly poorer in coal seams, both in the number of the seams and in their thickness, than the same strata in the eastern part of the Raniganj coalfield. I have recognised the following subdivisions in the Raniganj series of the Jharia area :—

Name of stage.	*Coal seams.*
Lohpiti sandstones	No coal.
Telmucha coal measures	Lohpiti and Telmucha and other small seams.
Jamdih sandstones	No coal.
Murulidih coal measures	Bamangora, Machiraidih, Murulidih and Bhatdih seams.

Barren Measures.

The quality of the coal in the workable seams of the Raniganj series in the Mahuda basin, between the Jamunia *nala* and the Khudia stream, is shown below :—

Colliery and seam.	Moisture.	Ash.	Volatile matter.	Fixed carbon.	Calories.
	Per cent.	Per cent.	Per cent.	Per cwt.	
Murulidih or Bamangora stage.					
Koradih (basal ?)	2·20	15·12	27·68	57·20	7,403
Bamangora	1·64	16·15	28·75	55·10	6,944
Hatudih (bottom)	2·17	12·52	29·93	57·55	7,283

Colliery and seams.	Moisture.	Ash.	Volatile matter.	Fixed carbon.	Calories.
	Per cent.	Per cent.	Per cent.	Per cent.	
Hatudih (top Lower) .	2·27	17·95	29·15	52·90	6,844
Hatudih (top Upper) .	2·07	15·05	32·2	52·75	7,084
Jamdiha sandstones with silicified fossil wood, no coal.					
Telmucha coal measures.					
Pathargaria, Telmucha ., Lohpiti . } D seam .	2·11	18·80	28·40	52·80	6,607

Vitrain or bright coal.

In making analyses of the lump and slack samples of Damuda coals, it is often found that the finer material is often 2 or 3 per cent. lower in ash than the larger coal. This is due to the fact that the Damuda coals are characteristically banded, and that some of the laminae of jetty bright coal (vitrain) are both thick ($\frac{1}{4}$ to $\frac{3}{4}$ inches and more) and abundant. The material is very friable and in the necessary handling and stacking much of the vitrain crumbles away and becomes mixed with the slack. Analyses of *vitrain* from the Barakar and Raniganj seams of the Jharia field are shown below :—

——	Moisture.	Ash.	Volatile matter.	Fixed carbon.	Specific gravity.
	Per cent.	Per cent.	Per cent.	Per cent.	
Raniganj series—					
Lohpiti . . .	2·26	4·75	36·42	56·57	1·312
Barunga . . .	2·29	3·60	36·49	57·62	1·292
Huntodih . . .	3·03	1·21	34·80	60·96	1·307
Bamangora . . .	1·97	1·87	32·88	63·28	1·286

—	Moisture.	Ash.	Volatile matter.	Fixed carbon.	Specific gravity.
	Per cent.	Per cent.	Per cent.	Per cent.	
Barakar series—					
XVII seam Baliari .	1·67	3·97	31·24	63·12	1·308
XIV „ Chasnala .	1·73	2·11	30·87	65·29	1·280
XIV „ Phularitanr.	0·85	0·36	27·89	70·90	1·272
IX „ Karmatanr .	0·84	2·64	26·52	70·00	1·300
IX „ Keshalpur .	1·04	0·78	26·10	72·08	1·291
VII „ Matiagara .	1·08	2·72	23·02	73·12	1·318
I „ Lutipahari .	..	..	..	..	..

The ash analyses of a few of the better quality Barakar coals from the Jharia coalfield may be of interest. These particulars are calculated to 100 per cent.

Ash composition.

—	1	2	3	4	5	6
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica . .	52·55	51·10	59·20	44·68	56·35	50·52
Alumina . .	26·32	34·45	32·20	35·81	30·87	28·78
Ferric oxide .	7·00	6·80	3·80	5·14	8·00	8·28
Lime . .	7·70	4·00	1·44	7·42	2·25	5·00
Magnesia .	2·22	0·80	1·23	3·38	0·95	1·01
Phosphorus pentoxide.	..	1·87	..	1·69	0·92	3·63
Other constituents.	..	..	..	..	..	..

1 is No. XIII seam Baliari; 2 is No. XIV seam Ekra; 3 is No. XIV-A seam Standard; 4 is No. XV seam Barari; 5 is No. XVII seam Jamadoba; and 6 is No. XVII and No. XVIII seams Jamadoba. The total ash in these coals may be gauged from the analyses given above—roughly between 15 to 10 per cent.[1]

[1] *Mem. Geol. Surv. Ind.*, LVII, pp. 147-151, (1931).

Railways were opened in the Jharia coalfield about 1894, but coal had been raised for three or four years before. The total output of coal from then until 1930 was of the order of 200 million tons. Since about 1908, this coalfield has provided 50 per cent. of the total production from Indian mines in this country. Practically all the coal is of caking quality and especially that from seams above No. IX. Many of the larger colliery companies have established batteries of coke ovens of up-to-date type, and in most of these a recovery is made of coal tar, sulphate of ammonia, benzol; the waste gases are utilised for steam raising. In some instances large electrical power stations have been established for providing power to adjacent collieries. The question of general electrification, not only of collieries and for town lighting but also of the railways feeding the coalfield, has been considered. Economic conditions, however, have lately rendered these developments impossible and have even retarded the introduction of sand-stowing in the extraction of the coal. Most of the 'hard' (metallurgical) coke is used by the iron-smelting industry and for foundry purposes. The manufacture of 'soft' coke is thought by some to offer a great future for the coal industry, and this subject is receiving careful consideration, in order that the domestic consumption of coal in this form may save the loss of valuable manure and so increase the agricultural produce from the land.

Production and developments.

Details of the annual production of coal from the Jharia coalfield since it was opened in 1895 and given railway communication in 1897 are shown below :—

Year.	Output of Jharia.	Total for India.	Percentage.
	Tons.	Tons.	
1896	..	3,863,698	..
1897	333,436	4,066,294	8·2
1898	749,988	4,608,196	16·27
1899	1,007,236	5,093,260	19·77
1900	1,710,757	6,118,692	27·95

Year.	Output of Jharia.	Total for India.	Percentage.
1901	1,946,763	6,635,727	29·34
1902	2,420,786	7,424,480	32·60
1903	2,493,729	7,438,386	33·52
1904	2,889,504	8,216,706	35·17
1905	3,070,588	8,417,739	36·48
1906	4,076,591	9,783,250	41·67
1907	5,179,185	11,147,339	46·47
1908	6,458,643	12,769,635	50·58
1909	5,832,672	11,870,064	49·14
1910	5,794,616	12,047,413	48·10
1911	6,373,728	12,715,534	50·13
1912	7,653,452	14,706,339	52·04
1913	8,608,310	16,208,009	53·11
1914	9,146,653	16,464,263	55·55
1915	9,140,800	17,103,932	53·44
1916	8,950,318	17,252,309	51·87
1917	9,783,788	18,212,918	53·72
1918	10,952,010	20,722,493	52·85
1919	12,145,917	22,628,037	53·68
1920	9,294,040	17,962,214	51·74
1921	10,068,856	19,302,947	52·16
1922	9,936,299	19,010,986	52·27
1923	10,346,015	19,656,883	52·63
1924	10,845,642	21,174,284	51·22
1925	10,676,883	20,904,377	51·08
1926	10,373,736	20,999,167	49·40
1927	10,583,487	22,082,336	47·93

Year.	Output of Jharia.	Total for India.	Percentage.
1928	10,665,479	22,542,872	47·31
1929	10,785,745	23,418,734	46·05
1930	10,753,858	23,803,048	45·18
1931	9,755,037	21,716,435	44·92
1932	8,551,283	20,153,387	42·43
1933	8,014,949	19,789,163	40·51

Making allowance for the coal destroyed or rendered difficult of extraction by igneous intrusions, and excluding several thinner seams (under four feet), and making no allowance for the coal won and utilised since the field was opened, the total workable coal in the field was computed by me as shown below :—

Reserves of coal in the Jharia coalfield.

Geological stages.	Millions of tons at depths of		
	500 feet.	1,000 feet.	2,000 feet.
Raniganj series—			
Telmucha stage	18	30	30
Murulidih ,, ...	50	75	75
Barakar series—			
Phularitanr stage . . .	145	255	285
Barari ,, ...	473	748	911
Nardkarki ,, ...	630	1,150	1,600
Golakadih ,, ...	655	1,128	1,600
Extras .	36	36	36
Grand Total .	2,007	3,422	4,537

It is now accepted as probably correct that for every ton of coal hitherto raised in the Jharia coalfield, another ton has be-

come unavailable from one cause or another.[1] It would, therefore, be necessary to consider the raising of 200 million tons as involving 400 million tons in total. However, of the 200 million tons rendered unavailable, it is certain according to prevailing prices, that upwards of 100 million tons[2] could be recovered—it is not irretrievably lost. If my calculations require modification, to meet the exploitation and losses for the past 35 years, I would deduct only 300 million tons from the total reserves. As most of the coal raised has come from seams Nos. XIII, XVI, XIV-A and XV (Barari stage), and much from the Phularitanr and Nardkarki stages, I would portion out the deductions for despatches, local consumption, and loss as follows :—

	Million tons.
Tolmucha stage	1
Murulidih „	14
Phularitanr „	30
Barari „	180
Nardkarki „	50
Golakadih „	25

If these deductions are made from the above estimated reserve —themselves the absolute minimum and from which all *supposedly coked* coal has been eliminated—, then the available reserves of coal in the Jharia coalfield are as follows :—

Seam.	MILLIONS OF TONS AT DEPTHS OF		
	500 feet.	1,000 feet.	2,000 feet.
Tolmucha stage	17	29	29
Murulidih „	36	61	61
Phularitanr „	115	225	225
Barari „	293	568	731
Nardkarki „	580	1,100	1,550
Golakadih „	630	1,103	1,575
Extras	36	36	36
TOTAL	1,707	3,122	4,237

[1] According to details given by Mr. R. G. M. Bathgate.
[2] By the employment of sand-stowing.

The most serious aspect of these remaining reserves is the amount in the Phularitanr and Barari stages. In these coal measures are the chief coking coal seams of the Jharia coalfield —in fact of India. These seams Nos. XVIII, XVII, XVI, XV, XIV-A, XIV and XIII, are not all equally good in quality. The total available reserves, exclusive of any unaltered coal in the coked areas, are strictly limited. The total quantities in the Phularitanr and Barari stages are—

408 million tons within 500 feet,
793 million tons within 1,000 feet, and
956 million tons within 2,000 feet of the surface.

It may be said without fear of contradiction that the life of the Jharia coalfield will depend largely on the reserves of good-quality coking coal in the Phularitanr and Barari stages. These reserves are now seen to approximate to 800 million tons within a depth of 1,000 feet. A similar total, *i.e.*, 883 million tons in seams Nos. XVIII, XVII, XVI, XV, XIV-A, XIV and XIII, has been arrived at by N. Barraclough in his paper 'The Coal Resources of the Jharia Coal-field '.[1] This writer has shown that the quantity of selected and first-grade coal obtained from the Jharia coalfield up to the end of 1927 is roughly 136 million tons.[2] These grades, as stated in the previous paragraph, are almost entirely restricted to the Phularitanr and Barari stage seams (Nos. XIII to XVIII). Making allowances for loss from fires and subsidence, and including the coal left in pillars (as depillaring operations are not actively engaged in), it may be broadly stated that for every ton of coal raised from the seams in question, an equal quantity has been rendered unavailable by existing methods of working.

The annual despatches of *selected* and *first grade* coal from the Jharia coalfield may be computed at from eight to ten million tons. It may, therefore, be concluded that 16 to 20 million tons of coal from the seams of the Phularitanr and Barari stages are being absorbed every year. At this rate the reserves to a depth of 1,000 feet must be exhausted within 40 to 50 years, unless the methods of working can be improved in the near future. The adoption of sand-packing or hydraulic stowing, the only remedy against loss by fires, subsidence, and coal left as pillars and bar-

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 384, (1929).
[2] *Loc. cit.*, p. 689.

riers, appears to be impossible with the price of coal as it is to-day. On several occasions during the past decade, the subject has been brought to the notice of those engaged in the extraction of coal in the Jharia field and must now be quite familiar. Nevertheless little has been done and a retrograde movement has in fact taken place. In this respect it appears useless to expect any serious action to be taken at present by firms in the coal industry.

It is interesting to note that the cost of sand-stowing must vary according as collieries are near or distant from the source of supply of sand. It is certain that no colliery operating seams in the Phularitanr and Barari stages will be more than seven miles from the Damodar river. It is computed that the cost of sand-stowing near the river, between Amlabad and Chasnala, where the best deposits of sand occur, is roughly eight to ten annas per ton of coal raised, and that the cost will increase roughly at the rate of 1·5 annas per mile away from this stretch of the Damodar river. It would seem feasible to grant collieries a rebate on freight on some such sliding scale and oblige them to adopt sand-stowing, especially in seams Nos. XIII to XVIII.

When it is remembered that it is from the seams of the Phularitanr and Barari stages that perhaps over 50 per cent. of the best coal in India is produced, it does not seem unreasonable that active steps should be taken to conserve supplies. It is also largely from these seams that supplies of railway coal, for locomotives, are obtained, and also coal for the preparation of metallurgical coke. And it is these same seams that have provided the coal for export since the establishment of the Coal Grading Board. They are by far the most valuable reserves of coal in India, and this loss of 50 per cent. in extraction should be prevented.

The computation of the coal reserves was the essential purpose of the re-survey of the Jharia coalfield and the preparation of a new geological map, on a scale of four inches to the mile. The value of these reserves depends on the quantity of good quality coal—an amount estimated in seams Nos. XIII to XVIII at only 800 million tons. Of this very limited total only one half—400 million tons—appears likely to be *available* by the methods of extraction now in vogue; nor may even this quantity be secured with safety. It is absolutely necessary to prevent a continuance of such unnecessary squandering of these reserves in the Jharia coalfield.

Chandrapura Coalfield.

This little area in the extreme west of the Jharia field and connected with it by a strip of Talchirs, is really part of it. It consists of roughly 400 acres of Barakar rocks, with nine coal seams south and south-east of Chandrapura railway station (23° 45′ 20″ : 86° 7′ 20″) on the East Indian Railway, connecting Gomoh with the Bokaro and Karanpura coalfields and Daltonganj. Some of the seams are of more than 12 feet thick, and we may safely estimate an average thickness of 30 feet, to cover damage by faults, folds and dykes. If we estimate the workable area as 320 acres, or half a square mile, these strata contain 15 million tons of coal of the lower Barakar—Muraidih and Nardkarki stage—measures. The quality of the coal is considered to be inferior; but, without further examination, it is not possible to say that there is no good coal in the area. Much of it is certainly of fair (II grade) quality quite suitable for brick burning and similar purposes.

Sherwill's Coalfield.

On a geological map made by Capt. W. S. Sherwill, Deputy Surveyor General, dated 1852, of the area including the Rajmahal hills and the Son valley a small tract of coal measures is shown about 12 miles W. N. W. of Chas (23° 38′ : 86° 10′) and would be quite distinct from the Bokaro field. The Jharia coalfield is not shown on that map and was not discovered till a few years later (1862), by Major J. L. Sherwill, who was engaged on the Revenue Survey there. As the above map has been found reliable in other respects, and as mention was made of the discovery of fragments of coal by Lieut. J. Delamain[1] at the crossing between the villages of Gomea and Angbally, it seemed possible that an outlier of Damuda rocks may occur in the Kanjo river above (south of) Angwali (23° 43′ : 86°).

Unfortunately this area had not been specially revisited since 1860, and the reliability of Sherwill's map was demonstrated in December, 1930, after I had left the Jharia coalfield. During my survey of the Jharia coalfield, I had repeatedly heard of coal being found in the vicinity of Bhojudih (23° 38′ : 86° 27′) where, however, I could not find any sign of Gondwana rocks. Later on

[1] *Journ. As. Soc. Beng.*, XI, p. 832, (1842).

I asked the late Rao Bahadur Sethu Rama Rau, one of my survey party, to make a careful search of the country south of Bhojudih. He was able to visit the supposed locality of the occurrence and found dark gneissic rocks—hornblendic schist and gneisses. The Bhojudih area is some distance east of Chas, and the lack of coal in the one place does not exclude the possibility of an outlier where such is marked on Sherwill's map. Finally, in December, 1932, my colleague Dr. J. A. Dunn made a special trip to the Kanjo river *viâ* Chas and traversed the area of Damuda rocks shown on Sherwill's map. Dr. Dunn tells me he found no trace of any Gondwana rocks, either *in situ* or detrital material, in Kanjo river. Thus the mystery of the supposed occurrence of coal-bearing Damuda rocks south of the Jharia and Bokaro coalfields remains.

CHAPTER 8.

COALFIELDS OF BIHAR—*contd.*

DAMODAR VALLEY COALFIELDS—*contd.*

Bokaro Coalfield.

This long narrow strip of Gondwana rocks, roughly 40 miles from east to west and less than seven miles from north to south, lies in a belt of trough-faulting. The eastern end of the field at Chirudih (23° 46′ : 86° 5′) is within two miles of the tongue of Talchirs which extends westward from the Chandrapura section of the Jharia Gondwanas. The western end of the Bokaro coalfield continues beyond the Ranchi-Hazaribagh road to near Kodwe (23° 44′ : 85° 25′), barely two miles from Rikba, and about a mile from the eastern edge of the North Karanpura coalfield. It is thus north-west of the Argada end (23° 39′ : 85° 28′) of the South Karanpura field. The name was given by Mr. D. H. Williams about 1846-47 when he examined this area and noted that it was traversed for over 25 miles by the Bokaro river, which joins the Kunar near Hazari (23° 47′ : 85° 52′), the latter discharging into the Damodar at Jarangdih (23° 46′ : 85° 55′). Mr. T. H. Hughes[1] was in favour of using the name of the lofty hill of Lugu to indicate the field.

'Standing as the hill does, in the middle of a plain, and rearing its summit far above any other eminence in the neighbourhood, it is the most prominent natural object which meets the eye for miles around, and could never fail to attract attention to itself.'

Communications.

The East Indian Railway branch line (known as the Central Coalfields Railway) from Gomoh and Chandrapura passes through the Bokaro coalfield from east to west by Dhori and Gumia (23° 48′ : 85° 50′) and along the north of Lugu Hill (3,203 feet; 23° 47′ : 85° 41′) south-west by Argada, to Barkakana (23° 37′ : 85° 28′). Thus the Barakar coal measures seen on both sides—east or Bermo (23° 47′ : 85° 57′) wing and west or Kedla (23° 47′ : 85° 35′) wing—of the central tract of Lugu Hill, are served by a broad gauge line connecting it

[1] *Mem. Geol. Surv. Ind.*, VI, p. 39, (1867).

with Calcutta and north-west India. The motor road from Ranchi to Hazaribagh passes through the West Bokaro area, with a branch road from its north-west corner near Charhi (23° 51′ : 85° 30′) into this part of the field at Leiyo (23° 47′ : 85° 38′). In East Bokaro a motorable road connects Sawang (23° 48′ : 85° 50′) with Kargali and Dhori (23° 46′ : 85° 59′), northwards with the Grand Trunk Road about mile 202 near Dumri; there is at present no connexion eastwards with the roads of the Jharia coalfield.

Geological features.

As already stated, the field was examined by Mr. Williams between 1846 and 1848, and geologically surveyed by Mr. Hughes in 1866-67. It has not been entirely re-surveyed since, although it was carefully searched by the geologists of Bokaro and Ramgur, Ltd. Most of the Gumiya section west of the Kunar river to Gumia of East Bokaro, and much of West Bokaro (around Kedla and Jharna) was mapped in great detail (on a scale of 16 inches to the mile) by Dr. L. L. Fermor in 1916-17. It is very unfortunate that Dr. Fermor's mapping was stopped on the completion of his examination of the coal measures. The only available complete geological map still is that which accompanies Mr. Hughes' memoir. However, it is clear that the coalfield has been preserved by the trough-faulting. The enormous amount of denudation which has taken place in this region can be gauged by the mass of Lugu Hill in the centre. The difference of level between the relatively flat country of East Bokaro about Kargali (on Middle Barakars) and the Mahadeva summit of Lugu Hill, is not less than 2,500 feet. The deepest part of this Bokaro coalfield is under Lugu Hill, as it is also the highest point of the Gondwanas in this tract. Talchir rocks show up at the east and west ends of the field from below the Barakars. Small areas of Talchirs and Barakars occur outside the north boundary fault near Daridag (23° 49′ : 85° 48′) and east of Gobindpur (23° 48′ : 85° 53′). The field contains all the subdivisions of the Damudas—the coal measures of the Barakars, conformably overlaid by Upper Barakars or Middle Damudas (the Barren Measures of Jharia and the Ironstone Shales of Raniganj), and the Raniganj series, which so far appear to contain few workable coal seams. The Raniganj series is also thought to be slightly unconformable to the Middle Damudas. The Panchets, which form the plinth of Lugu Hill, are also unconformable to, and evidently overlap, the Raniganj series westwards under Lugu Hill. If the capping sandstones of

Lugu Hill are the equivalents of those of the summit of Panchet Hill, and are therefore correlated with the Dubrajpur beds of Rajmahal and the Mahadevas of the Satpura region, there is obviously a great hiatus between them and the Panchets below them under Lugu Hill. Besides the great east to west boundary faults there are several cross and oblique faults in the Bokaro coalfield. Dykes of dolerite and of mica-peridotite are nearly as common in this field as in that of Jharia. Some of the borings put down under the guidance of Dr. Fermor have shown that the coal seams have been seriously affected in places. There is possibly no better area in India for the study of the baked and fused strata, associated with the 'burnt outcrops' of coal seams, than that between Kargali and Sawang. They have been specially described by Dr. L. L. Fermor in a valuable paper.[1]

In discussing the Bokaro coalfield, it seems advisable to consider it in two sections :—East Bokaro, that portion east of Birhudera; in longitude 85° 42′ and West Bokaro, from Lalgarh (85° 42′) westwards. At present all mining has been concentrated in East Bokaro and east of Gumia (23° 48′ : 85° 50′), and practically restricted to the Kargali seam. Bokaro and Ramgur, Ltd., are working in the Dhori area; the large quarries and pits worked at Kargali belong to the Great Indian Peninsular Railway; the quarries and pits about Bokaro and Bermo are under the control of the East Indian Railway and the Bengal-Nagpur Railway jointly, as are also the workings being developed near Sawang; the Bombay, Baroda and Central India and the Madras and Southern Mahratta Railways will draw supplies of coal from their own pits at Jarangdih (see Plate 9). In every case the operations are being carried on only in the Kargali seam, which in one section in the Bokaro quarry was found to be 125 feet thick, including thin carbonaceous shales (see Plate 6). Besides the Kargali seam, there are several others: the more important in downward succession are :—

East Bokaro field.

12-foot A seam;
Kargali (100-foot) seam;
Bermo (40-foot) seam and
Karo (80-foot) seam.

[1] *Trans. Min. Geol. Inst, Ind.*, XII, p. 52, (1928).

Dr. Fermor, by his maps and by boring has recognised 29 coal seams in the Barakars of East Bokaro. Several of these seams are under four feet in thickness, but, even excluding those of four feet and under, there are 19 seams over four feet thick. Dr. Fermor's sub-divisions of the Barakar coal measures may be quoted as follows[1]:—

Strata and total coal and seams.	Chief coal seams.	Rock between seams.
Middle Damudas or non-coal-bearing strata (Barren Measures) chiefly sandstones and shales.		2,750 feet.
		278 feet.
Lower Damudas	No. 25, L seam, 16 feet.	
Upper sandstones and shales with thin coal seams 1,050 feet, rock 982 feet, coal 68 feet in ten seams.		56 feet.
	K seam, 13 feet.	
		41 feet.
	J seam, 5 feet.	
		26 feet.
	I seam, 6 feet.	
		214 feet.
	H seam, 4 feet.	
		126 feet.
	G seam, 6 feet.	
		285 feet.
	No. 15, F seam, 12 feet.	
		94 feet.
	E seam, 6 feet.	
Middle sandstones and shales with thick coal seams 1,095 feet, rock 863 feet, coal 232 feet in six seams.		140 feet.
	No. 13, D seam, 58 feet.	
		125 feet.
	No. 12, seam, 27 feet.	
		124 feet.
	No. 11, seam, 46 feet.	
		302 feet.
	No. 10, C seam, 3 feet.	
		23 feet.
	No. 9, B seam, 29 feet.	
		149 feet.
	No. 8, A seam, 69 feet.	
Lower grits sandstones and shales with thin coal seams, rock 396 feet, coal 25 feet in seven seams.		140 feet.
	...	421 feet.
Basal grits and conglomerates .	..	128 feet.

[1] In the above lists, seam No. 13 is the Kargali seam which varies from 41 to 123 feet in thickness. The letters refer to the seams recognised by Mr. David. The numbers refer to seams identified by Dr. Fermor and are *not* a correlation with the seams in Jharia. Seam No. 12 is not named. Seam No. 11 is the Bermo seam. Seam No. 9 is not named by Dr. Fermor and seam No. 8 is, of course, the Karo seam. The Kargali seam is in two seams at Dhori Colliery :—upper coal 32 feet, strata between 40 feet and lower coal 38 feet, but to the dip, westward, the parting rapidly thins to two feet of shale in 75 feet of coal. The upper 25 feet of the lower section is of good caking quality at Dhori; but it is now established that the Kargali, and other seams which yield good coal, are also of caking quality.

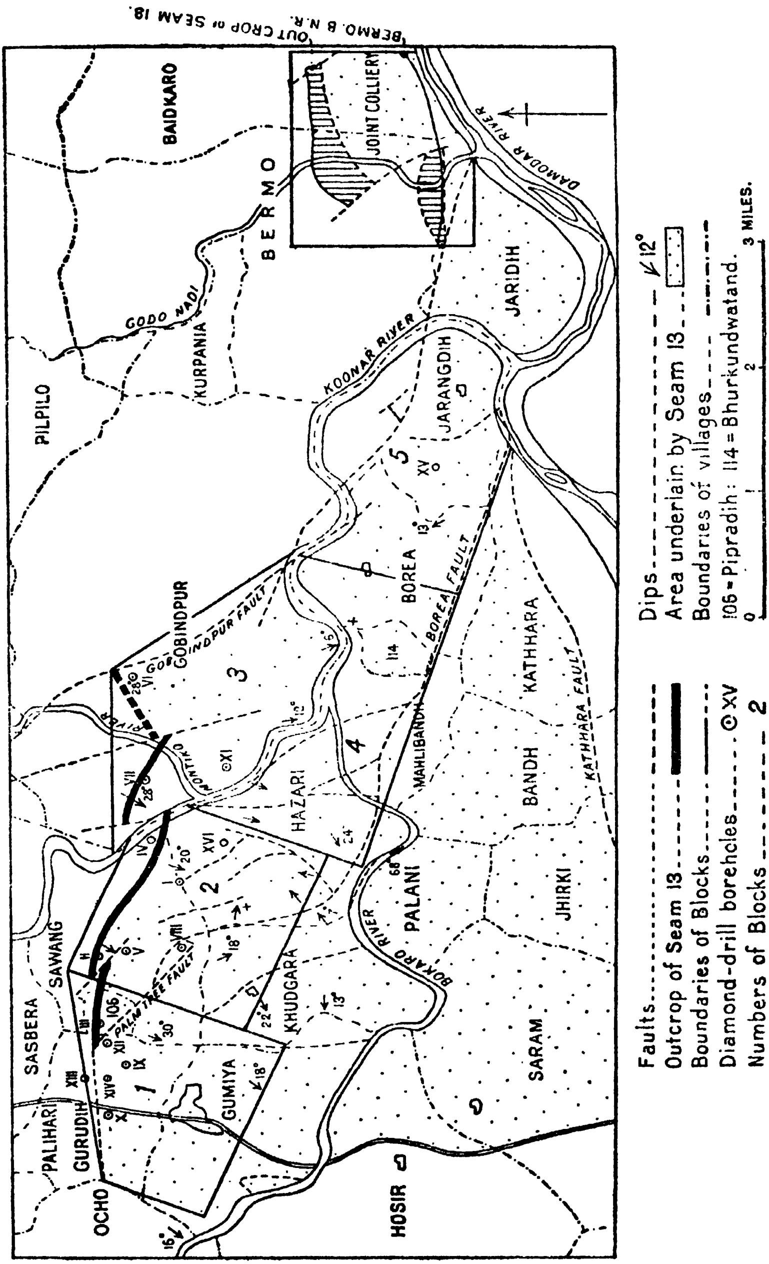

FIG. 1.—Sketch map showing boreholes in the East Bokaro coalfield.

Borings in East Bokaro.

The sketch map forming Fig. 1 on page 123 shows the position of the several boreholes put down by Dr. Fermor, and the details of the rocks met with in each boring are shown in section. Probably the most important of these borings is that at Jarangdih (No. XV) (Fig. 2) in

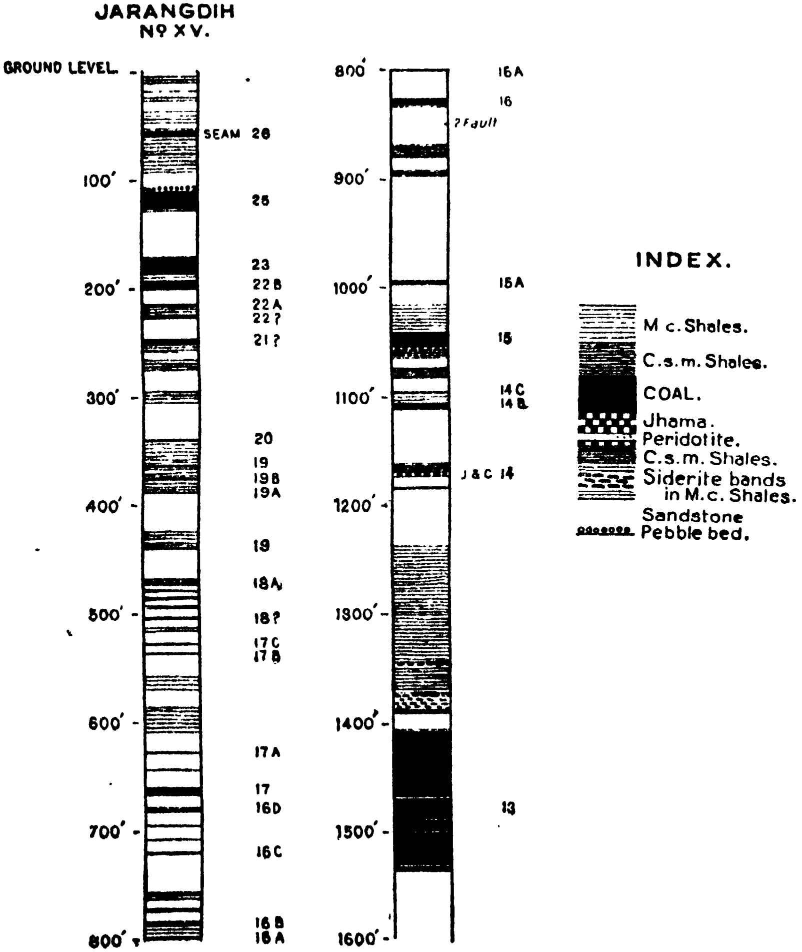

FIG. 2.—Jarangdih boring.

M. c. shale—mica-carbonaceous shale, and is the very fine-grained black shale.

C. s. m. shale—carbon-silica-mica shale, and has many varieties. It is coarser grained than M. c. shale, and often grey or bluish rather than black. It may pass into M. c. shale in one direction and shaly sandstone in the other. It often carries the fossil *Vertebraria indica*.

which seams Nos. 26 to 13 (the Kargali seam) were met with. The Kargali seam was found at a depth of 1,407 feet and passed through at a depth of 1,535 feet, thus showing 121 feet 6 inches thickness, made up as follows :—

	Feet.	Inches.
Coal	0	1
mic. carb. shale	0	2
coal	60	3
coaly shale	0	1
coal	0	11
carb. shale	0	9
coal	17	0
carb. shale	0	3
coal within shale bands	8	6
carb. shale	0	3
coal	33	3
coaly shale	4	0 (excluded).

Two other borings, VIII (Sawang) to a depth of 966 feet and XI (Gobindpur) to 1,158 feet, proved the Kargali seam to be thinner than at Jarangdih, and also to be affected by mica-peridotite intrusions, as shown below :—

No. VIII.

	Feet.
Coal	15
Coal, partly coked	3
Jhama with mica-peridotite	22½
Peridotite	6
Jhama	3
TOTAL SEAM	49½

No. XI.

	Feet.	Inches.
Coal	21	0
Jhama	0	4
Peridotite	0	4
Coal	26	10
TOTAL SEAM	48	10

Dr. Fermor records that, when the shafts of the Joint (East Indian Railway and Bengal-Nagpur Railway) colliery at Bokaro were being sunk, Mr. J. Brown took samples of the coal from the

Kargali seam, at each foot in the total thickness of 89 feet. The ash analyses are shown below :—

Footage.	Ash contents.	Footage.	Ash contents.
Feet.	Per cent.	Feet.	Per cent.
0 to 7 . . .	19·45	50 to 55 . . .	15·74
7 to 12 . . .	12·11	55 to 60 . . .	14·52
12 to 17 . . .	16·49	60 to 65 . . .	16·43
17 to 24 . . .	14·27	65 to 68 . . .	16·72
24 to 29 . . .	23·07	68 to 73 . . .	14·90
29 to 34 . . .	16·30	73 to 82 . . .	20·99
34 to 40 . . .	17·80	82 to 87 . . .	14·54
40 to 46 . . .	15·82	87 to 89 . . .	20·12
46 to 50 . . .	28·76	Average 89 . .	17·45

As Dr. Fermor states, in actual practice the entire thickness of the seam is worked in the quarry area of the Joint colliery; and a sample taken by him from 24 railway wagons from this colliery showed (sample F. 153) :—

Quality of coal.

	Per cent.
Moisture	1·16
Volatile matter	23·57
Fixed carbon	58·96
Ash	16·31
Sulphur	0·465
Calorific value	7,140 calories.

Other analyses of the Kargali seam in the Sawang area of the East Indian Railway and Bengal-Nagpur Railway colliery (quarry) are shown below. These are from the Coal Grading Board's records.[1]

—	1	2	3	4	5	6	7
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture . .	1·59	1·48	1·52	1·49	1·58	1·39	1·34
Volatile matter .	28·20	29·65	28·18	27·95	31·08	29·28	29·95
Fixed carbon .	55·10	53·05	57·07	51·80	53·92	53·32	50·77
Ash . . .	16·60	17·30	14·75	20·25	15·00	17·40	19·28
Calorific value .	6,871	6,914	7,070	6,610	7,110	6,873	6,612 (calories)

In the above table, 1 is the bottom 5 feet; 2 the next 7 feet 11 inches; 3 the next 5 feet 3 inches; 4 the next 5 feet 4 inches; 5 the next 9 feet 5 inches; 6 the next 10 feet 6 inches; and 7 the top bench of 6 feet 5 inches.

[1] The Chief Mining Engineer, Railway Board, has no recent average analysis of the Kargali seam which varies from 75 to 140 feet in thickness. He states that there is about 16 feet in the upper part of the seam in which the percentage of moisture is 1·50, ash 12·30, volatile matter 24·98 and fixed carbon 62·72 and calories 7,345. The average ash of the whole seam is estimated at 17 per cent. He states that a seam 16 feet thick which outcrops and is roughly 1,200 feet above the Kargali seam, *i.e.*, above L seam evidently, has recently been examined, and that a six-foot six-inch section of it has yielded the following analysis of a fair sample :—percentage of moisture 1·88, ash 13·40, volatile matter 27·75, and fixed carbon 58·85, and calories 7,313 (dry basis).

At the eastern end of the field, where the Kargali seam is of caking quality, the analyses of the coal and the coal ash in Dhori colliery (as kindly supplied by the Chief Engineer, Railway Board) are, for the Upper section exclusive of shale bands, as follows :—

Coal.	No. 2 incline.	No. 6 incline.
	Per cent.	Per cent.
Moisture	1·00	1·10
Volatile matter . . .	24·60	25·50
Fixed carbon . . .	62·30	63·70
Ash	13·10	11·30
Calorific value . . .	7,300 calories.	7,507 calories.

Ash.	No. 4 quarry.	No. 5 quarry.
Silica	51·05	48·00
Alumina	37·43	34·85
Iron oxide	4·80	9·00
Lime	3·25	2·62
Magnesia	0·70	0·85
Alkalies	trace	trace
S. anhydride	0·62	0·86
Phosphoric anhydride . .	2·32	3·70
	100·17	99·88

Reserves of coal in East Bokaro.

Dr. Fermor's estimate of the amount of coal only in the Kargali seam, underlying the villages of Palihari-Gurudih, Sawang, Gumia Khudgora, Hazari, Gobindpur, Mahlibandh, Bhurkundwatanr, Borea and Jarangdih (about ten square miles), with a mean thickness of 76 feet (41 to 50 in the north and 121 feet in Jarangdih) gives roughly 760,000,000 tons. Dr. Fermor takes an average thickness of 65 feet and allows for the somewhat heavy coal (sp. gr. 1·45), and estimates 730,000,000 tons. After allowing 37·5 per cent. for faults and loss in picking, and another 12·5 per cent. for natural

coking (*i.e.*, 50 per cent. in all), he arrives at a total of 365,000,000 tons in this ten square miles in the Kargali seam alone. It is to be remembered that he has not included the areas being worked eastward of east longitude 85° 55′, in which lie the quarries of Bokaro, Kargali and Dhori—an area of quite five square miles, or half as much again possibly, only in this Kargali seam. It may thus be safely asserted that the reserves in the East Bokaro field in the Kargali seam alone are upwards of 500,000,000 tons of good coal; it may be taken as certain that most of this is of good caking character and, if cleaned, is suitable for yielding metallurgical coke. If the inferior coal in the Bermo and Karo and other seams is included the quantity is easily upwards of 1,000,000,000 tons half of which is of good caking quality. Dr. Fermor's conclusions (restricted to the ten square miles mentioned by him) are:—

'In East Bokaro one seam is of outstanding value, namely seam 13, or the Kargali already being worked at the East Indian Railway and Bengal Nagpur Railway Joint Colliery, and at the Great Indian Peninsula Railway Colliery, to the east of the Gobindpur fault. To the west of this fault (the Gumiya section of the field) the Kargali seam varies in thickness from 41 to 121 feet, and underlies at least 10 square miles of ground; and after making a deduction of 50 per cent. to allow for faults, picking, and natural-coking due to mica-peridotite intrusions, it is estimated that this area contains 365,000,000 tons of coal averaging about 16 per cent. in ash contents and 7,000 calories in calorific value, which is also the quality being railed from the Joint Colliery.'

Production of coal from the Bokaro coalfield.

The annual production of coal from the Bokaro coalfield is shown below:—

Year.	Tons.	Year.	Tons.
1908	..	1917[1]	360,760
1909	2,544	1918[1]	541,977
1910	3,390	1919	722,682
1911	468	1920	857,522
1912	8,258	1921	920,143
1913	3,319	1922	1,037,171
1914[1]	16,920	1923	1,060,366
1915[1]	10,232	1924	1,343,500
1916[1]	197,255	1925	1,494,966

[1] Includes Rajmahal.

Year.	Tons.	Year.	Tons.
1926	1,514,918	1930	2,160,249
1927	1,790,594	1931	1,656,597
1928	2,026,791	1932	1,348,973
1929	2,118,703	1933	1,304,864

Lugu Hill area.

This area, from Sarum (23° 46′ : 85° 49′) to Daka Sarum (23° 47′ : 85° 39′), includes the mass of Lugu Hill, and is chiefly covered by rocks younger than the Barakars. It includes a large tract of East Bokaro and a little of West Bokaro—areas that have not been fully examined. However, coal has been met with in the thin strip of Barakars extending along the northern margin of this part of the field. Mr. Hughes[1] mentions a poor exposure near Uda (23° 48′ : 85° 47′), about 2½ miles west of Gumia. He draws attention to better sections opposite Lalgarh and at Karipanitola, north-west of the point of Lugu Hill. It is thus clear that the Barakars will on the whole be under the younger strata. In the area between Sarum and the mass of Lugu Hill the Barakars are successively overlain by the Barren measures, the Raniganj series, the Panchets, and finally by the Mahadevas, so that the coal measure strata of the Barakars will be too deep to be workable for very many years to come. But on the north side of Lugu Hill, in the valley of the Bokaro river, it seems that the Panchets overlap the intervening beds and rest directly on the Barakars.

As the chief seams of East Bokaro are thought to belong to the middle portion of the Barakars, and the erosion of the Damudas has permitted the Panchets to rest on Barakars, between Lalgarh and Daka Sarum, there is a possibility that these middle Barakar seams are not at considerable depths in the area immediately north-west of Lugu Hill. But it is evident that, while the thick seams of East Bokaro are available, little effort will be made to prove the area mentioned by an expensive series of bore-holes. These efforts, in view of the known quality of the seams in East Bokaro, would have to aim at finding the Kargali seam ; and to find or recognise this

[1] *Op. cit.*, p. 69.

seam will require detailed geological mapping of the whole of West Bokaro. And Dr. Fermor has estimated that

'a thorough study of the economic possibilities of West Bokaro, including a detailed geological survey........would probably take not less than 3 years, on account of the faulting, which will render very difficult the correlation of the seams.... '

Raniganj series coal.

Mr. Hughes records a few occurrences of coal seams in the Raniganj series in East Bokaro: (1) south of the Sarum-Khodwa road; (2) between Pindra (23° 47′ : 85° 45′) and Tulbul (23° 47′ : 85° 46′); and in West Bokaro: (3) near Basantpur (23° 49′ : 85° 34′); and (4) in the *nala* near Pindra (23° 50′ : 85° 31′) and Taping (23° 50′ : 85° 30′). But the seams of the Raniganj series seem to be few, thin and generally unattractive, as compared with the Barakar coal seams of the West Bokaro area, which are evidently not as good as those of the East Bokaro field.

West Bokaro field.

Mr. Hughes mentions that one of the best sections in the whole field is met with in the Bhagalata *nala*, evidently that flowing south into the Chutua river, from the old tea gardens of Jhumra Pahar (under the south-west slopes of Jilunga Hill, 3,057 feet; 23° 50′ : 85° 40′) through Morha, to its confluence a mile north-east of Leiyo. In the section given by Mr. Hughes[1] there are 11 coal seams—the top (2) 1 foot 7 inches, the next below (6) one foot; then (16) 4 feet 7 inches; then (19) 9 feet 6 inches; then (25) 13 feet (two feet good); next (27) good coal 16 feet 8 inches; and (31) inferior coal 3 feet 6 inches; and (34) six feet good coal, two feet stony coal; next (38) superior coal 1 foot 8 inches; finally two lower seams (40) and (43), which are thin and poor. Knowing how difficult it is to gauge the thickness of a seam of coal in any natural section, it would seem an excellent place to prove these strata by boring between Leiyo and Danea, as the beds dip southward. There is a synclinal structure present in the Chutua river section, below Rehaon down the stream, in which several coal seams were noted both by Mr. Williams and later by Mr. Hughes. In the little stream north of Kedla there is an outcrop of a 12-foot seam, and coal with carbonaceous shale occurs near Ichakdih; and south of Kedla near Jharnatoli there is an outcrop in the *nala* west of the hamlet.

[1] *Op. cit.*, pp. 71-73.

Coal has been found along the Bokaro river north of Tilaiya (23° 46′ : 85° 39′), and again at the outfall of the Jagesur *nala* west of Tilaiya. Further exposures are seen upstream near Ghosi (23° 46′ : 85° 37′) and higher about Garkia; and, according to Mr. Hughes, the middle Barakars are well exposed near Daka Sarum. Further coal outcrops are known high up the Bokaro river, above and below the junction with the Dudhi *nala*, east of mile 15½ from Hazaribagh on the Ranchi road. Other exposures occur within the drainage of the Chutua river near Duru Kasmar (23° 48′ : 85° 33′) and east of Banji.

Dr. L. L. Fermor has examined and sampled some of the seams of the West Bokaro area about Kedla and Jharnatoli, which had been previously seen by Mr. R. W. Church and also by Mr. Geo. Lathbury, whose opinions were not in agreement. It seems that, of the seams (Nos. 4, 7 and 8) which were tested in this tract, the ash content varied from 20·36 (No. 4) and 21·86 (No. 8) to 26·48 (No. 7 top) per cent. in these three seams. And concluding his remarks Dr. Fermor wrote :—

'With reference to West Bokaro the conclusion that must be drawn is that the particular seams investigated......do not contain workable thicknesses of either first-class or of good second-class coal. But although the prospects of West Bokaro seem unfavourable, only a detailed survey of the remaining portions of West Bokaro can finally determine this point.'

It will be seen later that the best seams of coal in the Karanpura coalfield occur, or are seen, in the eastern parts of those fields. The same curious fact is observable in the Jharia coalfield, and this is evidently true of the Bokaro field. It appears that the western ends of all these coalfields—Jharia, Bokaro and Karanpura—are more disturbed and less attractive than their eastern margins. The evidence suggests that the coal measures are really identical, and some of the seams probably the same from west Raniganj to western Karanpura, if only we could identify them. There is some reason why so marked a difference in quality and thickness should be observable within the limits of each field. The probability is that the seams are far less disturbed by faults and are better exposed in the eastern areas of each field and have thus received greater attention. Nevertheless, the fact remains that the eastern areas of these Damodar Valley coalfields appear to contain far more attractive seams of coal in the Barakar series than are found in the same strata in the western tracts of the same coalfields. About 1925 on

two occasions the West Bokaro area was carefully examined by borings on behalf of the Bokaro Ramgarh Limited Company by Dr. W. Chowdhury and later by Mr. E. H. Roberton. Between these investigations, the East Indian and Bengal-Nagpur Railways had jointly taken up a small area of 7,600 bighas (less than four square miles) near Kedla, within the boundaries of Kedla, Ichakdih, Leiyo and Rehaon. Bokaro Ramgarh Ltd. consider they had proved no less than 21 seams in the West Bokaro area. They were of the opinion that Nos. 7, 9, 10 and 21 (numbered from the base of the Barakars) were worth attention. Their borings have proved 13½ square miles in which 5 square miles are thought to be attractive. Their blocks A, B and C west of Kedla and another G (Kuju) about four miles south-west of Kedla may be summed up as below:—

Block.	Seam.	Area.	Thickness.	Quantity.
	No.	Bighas.	Feet.	Million.
A Kedla	7	3,200	19	18½
	9	2,500	6	6
	21	700	18	4
B (north)	7	2,000	10	8
(south)	10	2,500	10	10
C		not fully proved		
D		" " "		
E		" " "		
F		" " "		
G (Kuju)	Kuju	2,000	9 (top)	7½

The quality of the seams is such that, in nearly all cases, it is expected that hand-picking will be necessary to get a satisfactory grade of coal. In the case of No. 9 seam (six feet) of Kedla, No. 10 seam (ten feet) of Mandu in the south of block B, and in the Kugu seam (nine feet top), the coal appears to be of good quality. The full section of the Kuju seam is 18 feet, of which the following analyses have been placed at my disposal:—

——	Top nine feet.	Bottom nine feet.
	Per cent.	Per cent.
Moisture	3·65	2·45
Volatile matter	25·90	24·20
Fixed carbon	57·35	53·65
Ash	13·10	19·70
Calorific value	6,820	6,525 calories.
Caking property	Non-caking.	Non-caking.

These analyses suggest that the coals should be of caking quality, and information in regard to other samples shows that in some cases the coal is of caking quality. However, until the history of the samples and the method of ascertaining the caking property are given, it is not possible to say definitely that a coal of such composition as that of the Kuju seam is of non-caking quality. No. 7 seam is also known as the Duni seam, No. 9 is the Kedla seam and No. 10 is the Mandu seam; it is roughly 900 feet from the top of No. 21 seam to the base of No. 7 seam.

In addition to the blocks enumerated above, the areas to the east and west of those about Kedla, and also south of it through Ara to Leiyo and Danea to Jharna, required further examination, as there is little doubt that the seams of the proved areas must extend into them. Furthermore, the numbers given to the seams of West Bokaro must not be regarded as the same as those of East Bokaro, as no correlation has yet been made.

Ramgarh or Ramgurh Coalfield.

This coalfield was discovered by Mr. D. H. Williams about 1848, when making his surveys of the Damodar valley, generally in connexion with coal occurrences. He named it from the old town of Ramgarh (23° 37′ : 85° 31′), which is at the extreme western end south of the Damodar river, where it is crossed by the Ranchi-Hazaribagh road. The strata seen in this field consist chiefly of Talchirs and Barakars, but a small area of Middle Damudas and of Raniganj series is shown near Ramgarh on the map accompanying the reports on the Bokaro and the Ramgarh coalfields. The latter report is by Dr. V. Ball.[1] The Damuda (Barakar) rocks are 13 miles across from east to west, and are about seven miles wide, to which must be added a further mile of Talchirs at the north-east about Barki Punu (23° 41′ : 85° 42′). The area of the field is given as 40 square miles by Dr. Ball.

The field is traversed from end to end by the Damodar river, which turns north toward the Bokaro field, after emerging from the Ramgarh field, ten miles due south of Lugu Hill. Dr. Ball estimates the thickness of the strata as follows:—

		Feet.
Damudas	Raniganj series	?
	Ironstone shales	1,200
	Barakar series	3,000
Talchirs		850 to 900

[1] *Mem. Geol. Surv. Ind.*, VI, p. 109, (1867).

This would suggest a very complete set of the Barakar or chief coal measure formation. The south boundary of the field is cut off by a strong fault. There are several seams of coal seen in the Damodar above its junction with the Bhera *nala*, west of Hesapora (23° 38′ : 85° 44′). Dr. Ball refers to several localities where thick or thin crushed seams of unattractive appearance are seen. In some cases the quality is evidently fair, as coal has been carted to Ranchi, for sale as house fuel. The field is not free of dolerite dykes and possibly of mica-peridotite.[1]

Reserves of coal.

Dr. Ball states that the coal in the eastern part of the field occurs generally in thick seams with low dips, but that the quality is variable, and there is much interbedded carbonaceous shale. He considers that in the western part of the field the coal is not only of workable thickness, but of a better quality. Here unfortunately the seams dip at steeper angles and the coal is frequently crushed and cut off by faults. He adds :

'It does not seem probable therefore that the Ramgarh coalfield will ever be worked to any great extent.'

Subsequently Dr. Ball[2] gave it as his opinion that the field contained about 5,000,000 tons of coal, but he hints that this estimate may be subject to modification, if borings are put down and better data obtained. Seeing that the full thickness of Barakars are believed to be present, that no analyses of the coal are available, and that this area is evidently an outlier of the Bokaro field, it seems that the computation of the reserves is merely a shrewd guess. The area occupied by the Barakar coal measures is not less than 30 square miles and, taking one-sixth of this as having workable coal under it, the thickness of the seam need be no more than one foot to give five million tons which surely is very conservative, when thick seams are known to be present.

The Ramgarh coalfield has since been (after the War) examined carefully on behalf of a company known as Bokaro Ramgarh, Ltd. They considered the coalfield to average 30 square miles and to contain three thick seams of inferior-grade coal. These seams were a 36-foot, a 26-foot, and a 30-foot seam. Of these the middle section of the 26-foot seam looked attractive, and on examination it was

[1] *Loc. cit.*, p. 129.
[2] Manual, Vol. III, Economic Geology, p. 84, (1881).

found that, in a six-foot section about the middle of the seam, the quality was 16 per cent. ash in the lowest two feet; 34 per cent. ash in next foot, and 15 per cent. ash in the top three feet. These coal outcrops are nearly four miles from Chhitarpur station on the Bengal-Nagpur Railway. These results suggest that the Ramgarh coalfield is attractive only in having a workable six-foot seam out of which a foot of shaly coal will have to be picked by hand. If this seam is present under one square mile of land, the reserves in it will be five million tons, or the same as that estimated by Dr. Ball for the whole field, and for 30 square miles 150 million tons.

Production of coal.

During the period of high coal prices after the War, efforts were made to put the Ramgarh coal on the market, but the subsequent fall in prices rendered this somewhat inferior coal unsaleable. The details of production are shown below :—

Year.	Tons.	Year.	Tons.
1919	..	1924	5,905
1920	6,863	1925	2,548
1921	..	1926	585
1922	4,565	1927	340
1923	4,197	1928	386

Karanpura Coalfields.

The two areas of Gondwana rocks which comprise the Karanpura coalfields lie between 85° 28′ and 84° 46′ east longitude and 23° 38′ and 23° 50′ north latitude. The total area of both coalfields is roughly 550 square miles, of which perhaps 75 square miles belong to the south area. Mr. T. W. H. Hughes[1] gives the respective areas of the Damuda strata as 371 and 67 square miles. The actual date of the discovery of the larger field is not known. It was being examined by Mr. D. H. Williams[2] in 1848 when he died there. Mr. Hughes mapped the areas in 1867-68, *i.e.*, after Dr. V. Ball had found the smaller area of coal measures near Tungi (23° 40′ : 85° 26′).

[1] *Mem. Geol. Surv. Ind.*, VII, Pt. 3, (1871).

[2] 'A Geological Report on the Kymore Mountains, the Ramghur Coalfields, etc, edited by Dr. T. Oldham and published in 1852.

Mr. Williams had named the part of the northern area the Hoharo field, after a large stream in the eastern end of it. Dr. Ball named the smaller southern area the Tungi field, after a little village in its eastern tract. As both names were given provisionally and without a full survey of the rocks concerned, and as the importance of the coal measures was discovered during Mr. Hughes' survey, he was perhaps justified in changing these names to that of the Karanpura coalfields from the name of the pargana in which they largely occur. To-day we follow Mr. Hughes and speak of the smaller field in the south-east as the South Karanpura field, and of the larger area as the Karanpura or North Karanpura field.

The name.

The Karanpura coalfields were re-surveyed during 1915-18 by Dr. Albert Jowett[1], assisted by W. C. Grummitt, at first under the direction of Sir Thomas Holland, on behalf of Messrs. Bird & Co. of Calcutta. Dr. L. L. Fermor reported to the Railway Board on selecting and testing portions of the Karanpura coalfields.

The author spent a few days in the South Karanpura field at Arigada (Argada 23° 39′ : 85° 27′) and Saunda (23° 40′ : 85° 20′) and examined the Talchir exposure near Rikba (23° 45′ : 85° 22′ 30″) with Dr. H. Day who was then engaged on further surveys on behalf of Messrs. Bird & Co.

A great change has been produced throughout the Damodar valley by the extension of the railways from the East Indian and Bengal-Nagpur lines to Barka Kana (23° 37′ : 85° 28′), at the south-eastern edge of the South Karanpura field. From Barka Kana the East Indian railway continues up the Damodar valley, over the south-western end of the North Karanpura field, onwards to the Auranga and Hutar coalfields to Daltonganj, where connexion is made with the line up the Son valley. These railway facilities bring the South Karanpura coalfield into direct communication with Calcutta on the one side and north-western India on the other. In Mr. Hughes' day, the greatest drawback to the development of the Karanpura coalfields was the lack of means of communication.

Communications.

All the Gondwana formations of the Raniganj and Bokaro coalfields are present in the North Karanpura field. The basement beds—the Talchirs—occupy a very small area, as they only show in a few restricted outcrops.

Geological features.

[1] *Mem. Geol. Surv. Ind.*, LII, Pt. 1, (1925).

One of the best sites where well-preserved plant fossils occur in the Talchirs in India is that near Rikba discussed in my preceding memoir.[1] The Damudas are well developed and cover by far the greatest areas in both fields, as shown in an earlier paragraph. Both the Barakar and Raniganj series are seen and coal seams occur in each, although the Barakar series is easily the more important in the number and thickness of coal seams. Mr. Hughes and, after him, Dr. Jowett have mapped the intermediate strata—the Ironstone Shales; but during my visit I was convinced that a simpler subdivision into Barakars, Barren measures, and Raniganj series would be better for future working. Although Ironstones occur in the Barakars, the so-called Ironstone Shales themselves are not characterised by such beds as to warrant this name as more suitable than that of middle Damudas. In the Nalkari *nala* south-west of Saunda, I would unhesitatingly place all the beds mapped by Dr. Jowett as Ironstone Shales and part of the Raniganj series as Barren Measures. The Raniganj series of this section includes the equivalents of the Murulidih coal measures and Mahuda sandstones of Jharia (or the Sitarampur coal measures and Ethora sandstones of Raniganj).

The Panchets are also well seen in the North Karanpura coalfield along the base of the hills—of Maudih, Sathpahari, Malhan (Gerwa), and Tarhi near Ganeshpur—where they are capped by the so-called supra-Panchets or Mahadevas. Mr. Hughes has himself drawn attention to the presence of an unconformity of these higher beds on the Panchets[2] between Ango (23° 44′ : 85° 13′) and Batuka (23° 45′ : 85° 9′). No Panchets are seen in the South Karanpura field, where under the supposed Mahadeva outlier of Patal Hill (23° 48′ : 85° 7′) Barakars only occur. Dr. Jowett also draws attention to examples of unconformity in his memoir.[3] Both dolerite and mica-peridotite intrusions are met with in both coalfields. It is too early to say whether these latter intrusives are as they appear to be less abundant than in the Raniganj and Jharia coalfields. Faulting also seems to be less frequent than in the lower Damodar fields. There are strong east to west boundary faults along the south side of both these coalfields, although that north of Ango is on a parallel course to that of Chaingara (23° 37′ : 85° 25′), which is possibly related to that of Mahlan, though not exactly on the same strike line.

[1] *Mem. Geol. Surv. Ind.*, LVIII, p. 222, (1931).
[2] *Op. cit.*, p. 320.
[3] *Op. cit.*, p. 137.

South Karanpura.

The South Karanpura field consists of an elongated strip of Barakars along the Chaingara fault and has an outlier of Barren measures (with basal Raniganj coal measure strata), westward from south of Saunda to Binja (23° 40′ : 85° 13′). According to Dr. Jowett there is no outlier of Mahadevas at Patal Hill in the west, and the field is connected with that of North Karanpura by a small strip of Talchirs about Hosir (1½ miles north-west of Patal Hill). The North Karanpura field appears to consist of three so-called basins : the main area under the Mahadeva outliers of the Maudih (Mahudi) Hills, Sathpahari, and on to beyond Ganeshpur, practically forming a single large elongated basin with all the formations present ; the Mahlan (Gerwa) basin in the south-west corner and evidently belonging to the axial line of the South Karanpura field ; and the Chano (or Rikba) half basin, which is largely due to faulting, from north of Ango eastwards into the western end of the Bokaro coalfield. There is an inlier of gneisses between Chano and Lurunga in the valley of the Tordag *nala* (23° 46′ : 85° 20′), north-west of the Chano basin. Dr. Ball's village of Tongi in the South Karanpura field is at the eastern end of a somewhat larger gneissic inlier. Dr. Jowett's geological map suggests that the main or Mahudi basin is really sliced in three by faults trending east-south-east, and that the three could be readily designated the Mahudi, Sathpahari, and Tarhi sections of the main basin.

Structure.

Mr. Hughes calculated that in the Nalkari or Jainagar section of the South Karanpura field the total coal seen must be from 62 feet in eight seams to 159 feet in 16 seams. He takes a thickness of 70 feet, and allowing 20 feet of this for partings, estimates 50 feet over 15 square miles of the 67 covered by Damudas. This estimate, even for so small an area, gives 750,000,000, and not 75,000,000, tons as given in Mr. Hughes' memoir. As the area of Raniganj series (see above) is small in the South Karanpura field we need allow for no coal in these beds. In the North Karanpura coalfield there are several seams in the Barakars and three of workable thickness in the Raniganj series. Assuming, say, 30 feet of coal in the workable seams of the Barakars and five feet of coal in those of the Raniganj series, *i.e.*, a total of 35 feet of workable coal in the

Estimates of coal, South Karanpura.

Reserves in North Karanpura.

Damudas of the North Karanpura field, and estimating the area involved as 250 square miles (in 470), Mr. Hughes arrived at a reserve of 8,750,000,000 tons of coal in this field. Dr. Jowett[1] wrote :—

'Although only a small portion of the Karanpura Coalfields has been partially proved, some first class coal seams have been discovered and a greater number of second class seams.

The total quantity of first and second class coal must amount to between 5,000 and 10,000 millions of tons at least, without considering any coal below 2,000 feet from the surface. Thick seams of good quality which can be quarried have been proved in the South Karanpura Field.'

The view shown in Plate 10 of the quarry at Sirka illustrates the last sentence, but this is a smaller quarry than that at Arigada (Argada) a mile or so east of Sirka.

Recent developments.

Since Dr. Fermor, on behalf of the Railway Board, went into the question of choosing coal areas in the Karanpura coalfields, these areas have received considerable attention with a view to immediate development. It is, of course, known that though most of the Karanpura coalfields lie in the Hazaribagh district, some areas to the west and south fall within the boundaries of the Ranchi and Palamau district. Messrs. Bird & Co. evidently hold most of the areas in the Hazaribagh district, through the Karanpura Development Company. In 1930 the following mines and working leases had been taken up :—

The area about Arigada was being worked on behalf of the Bengal Nagpur Railway collieries; the quarries and mines at Sirka were working under the control of the South Karanpura Coal Co., Ltd.; Religara (23° 42′ 30″ : 85° 22′) was acquired on behalf of the Bombay, Baroda and Central India Railway, but had not been opened; Bhurkunda (23° 39′ : 85° 21′) Colliery was working on behalf of the State Railways; Chordhara, immediately east of Bhurkunda, was being proved for the Karanpura Development Company; Gidi (23° 42′ : 85° 42′) was owned by the Karanpura Development Company, as also Saunda which was being proved; Sayal or Porha (23° 42′ : 85° 21′) held by Messrs. Villiers Ld. had been given up; Messrs. Andrew Yule hold the concession just west of that of Sayal (Porha); and Urimari (23° 42′ : 85° 18′) which had been held by the Bengal Nagpur Railway, was given up for the Arigada area above mentioned. All these

[1] *Op. cit.*, p. 144.

areas lie in the South Karanpura field, and, so far as I know, little work has yet been done in the North Karanpura field. This may be explained both by the lack of suitable communications north of the Damuda river, and by the following remarks made by Dr. Fermor :—

'The evidence so far available does not point to the existence in North Karanpura of any 1st class coal; but only of 2nd class and 3rd class coal: and such prospecting work as is carried out will be for the purpose of enabling the Railway Board to discover and select areas containing good second class coal seams.

For this purpose I recommend a regular campaign on certain selected areas . . .'

The areas named by Dr. Fermor were :—

(1) Khapia (23° 46′ : 85° 22′ 30″), north of Rikba, which has both good and poor second class coal, but fairly high dips.

(2) Arahara (23° 53′ : 85° 14′), which has a thick seam showing both good and poor second class coal with lower dips than those of Rikba.

(3) Devalgara, a mile east of Ara (23° 50′ : 84° 57′), where the dips are favourable and the Ara seam may be expected.

And for poorer seams, Dr. Fermor suggested the following localities :—

(4) Indratoli (23° 46′ : 85° 18′).

(5) South of Honhe (23° 54′ : 84° 59′); and between

(6) Koilara (23° 44′ : 84° 59′) and Piparwar (23° 43′ : 85° 3′).

Seams in South Karanpura.

From notes made during my visit to this area, it appears that the shaft section of the Argada seam in the quarry at Arigada is as follows :—

		Feet.
Top section	Cover of earth, sandstone and clay	10 (approx.)
	Black mush and soft *coal*	6
	Coal	50
	Sandstone, shale and shaly coal	12
	Mixed *coal*	10
	Shale	4
Bottom section	*Coal*	38
	Shale	1 foot.

The coal from these seams, according to analyses made by the Coal Grading Board, is classed as first grade and belongs to the low volatile type.

In the adjoining property of Sirka the two Argada seams are separated by 17 feet of shales and sandstones and shaly coal. Messrs. Bird and Co. work the two Sirka seams which are about 20 feet thick each with a parting of 20 feet. There are roughly 60 feet of strata between the Upper Argada seam and the Lower Sirka seam. It is thought that the Argada seams are about the middle of the Barakars and somewhere near the horizon of No. X seam of Jharia, and possibly the representative of the Karo and Bermo seams of Bokaro, but this of course is a pure guess. It should be pointed out that there appear to be only three or four small seams below the Lower Argada seam, so that they may really be part of the Lower Barakars. The Sirka seams might be the representatives of the Kargali seam of Bokaro and possibly the horizon of Nos. XI and XII seams of Jharia (also a guess). It is known that the Sirka seams come together and are found as a single seam 40 feet thick in the Gidi area.

Dr. H. Day has recognised the following seams from his investigations around Saunda (between Gidi to the fault south of Jainagar) :—

Top.	Total strata in feet.
Saunda (10 feet) with three other seams	530
Balkudra double seam (20 feet top, 8 feet shale and 7 feet bottom)	400
Kursi (16 feet) seam	
Nalkari (7 feet) seam	
Another (7 feet) seam	
Simana (12 feet) seam (or U. Bhurkunda)	
Bhurkunda (6 feet) seam (or L. Simana)	
Hathideri (10 feet) seam	500
Thin seams (2 feet to 8 feet)	
Two seams (5 feet and 4 feet)	
Bansgarha (15 feet) seam	
Sirka (or Gidi) seam (40 feet)	280
Argada Top (85 feet) seam	
Argada Bottom (30 feet) seam	850
Several seams over 6 feet	
Base of Barakars (to Talchirs)	
TOTAL THICKNESS	2,500
TOTAL COAL	282

It is thus clear that the number and thickness of the seams, as well as the thickness of the Barakars in this area, is quite as well developed as in the best areas of the Jharia coalfield; but if even much more evidence were available, it is still improbable whether it

would be possible to correlate these seams with those of the Bokaro and Jharia areas. However, under existing conditions any such attempt must be misleading as the splitting, etc., of the seams in the Jharia field confuses the data. Further, the Sirka seams become one seam near Chordhara; the parting between the Argada seams increases to the westward (the Lower Sirka seam and the Upper Argada seam is thought to be the same) and is 150 feet in the Saunda area. The Balkudra seams, seen above the railway bridge over the Nalkari and up to the south boundary fault, are certainly very similar in their banded structure to seams Nos. XVII and XVIII of the Jharia field.

North Karanpura.

In the area north-west of Rikba, below the junction of the streams from Lurunga and Indratoli where occur the exposure of Talchirs with plant fossils there appears to be a wide outcrop of Barakars followed southward by beds containing coal which probably belong to the Raniganj series strata brought in by faulting. The section in the bed of the Indra stream is obscured by sand. There is not room enough for the full thickness of Barakars and the Barren Measures, and I am inclined to the view that a fault is present halfway down from the Talchir exposure (where, I feel sure, a fault separates the boulder bed from the plant bed in the Talchirs). Both Mr. Hughes and Dr. Jowett mention the occurrence of coal seams in the vicinity of Indratoli and Lurunga, and the geological map in the latter's memoir shows several areas of 'burnt outcrop' material (baked and fused shales, etc.), north-east of Lurunga and south-east of Isko, and again south-east of Gondalpura (23° 51′ : 85° 18′). Dr. Jowett[1] discusses the areas from Chano to Isko (pages 74-79) and Isko to Chandaul (23° 52′ : 85° 15′) very fully (pages 81-86) with regard to the coal seams and burnt outcrops of the Barakar series; and he gives similar details regarding the whole tract from Chandaul (pages 25-32) to Tarhesa (23° 54′ : 85° 6′) and on (pages 34-40) to Manatu (23° 53′ : 84° 56′), and round (pages 43-49) by Chakla (23° 44′ : 84° 48′) (pages 53-70) to Hosir (23° 42′ : 85° 7′), and finally to Ango, to complete the circuit of the Barakar outcrops of the main North Karanpura field.

Seams in North Karanpura.

[1] *Op. cit.*

As Mr. Hughes[1] did before him, Dr. Jowett has found several coal seams in this large sweep of Barakar rocks :—some near Ganeshpur, of over 72 feet in thickness[2], others again of west of Jala[3] of 90 feet; some between 12 and 24 feet—as mentioned by Dr. Jowett on pages 27 (near Arahara), 28 (near Urub), 30 (Jabra: 23° 55′: 85° 10′), 35 (Tarhesa), 37 (near Hohne), 46 (near Chamatu and Ara), 53 (near Mahuamilan; 23° 41′: 84° 48′), 59 (near Siram), and in other places; and there are several seams, upwards of four feet thick, in which the coal is said to be of good quality. It is to be remembered, however, that the areas mentioned have not been proved by boring as in the case the eastern area of the South Karanpura field.

Burnt outcrops in North Karanpura field.

Almost all the way round the Barakar outcrop, from Kura (23° 47′: 85° 22′) and Lurunga to Gali (23° 51′: 85° 20′) and again between Nawakhap (23° 54′: 85° 2′) and Sijua, and from Chamatu to Ara (23° 50′: 84° 57′) and the greatest extent of all in the tract north of the Damodar, from Henjda (23° 42′: 85° 0′) to Piparwar, there are evidences of coal in the baked and fused rocks where the seams have been on fire at their outcrop. As is now well known the seams are found intact at a relatively shallow depth, so that it is certain that coal exists in these localities even if it is not actually seen. Experience has also shown that for seams to take fire and burn with considerable evolution of heat generally means that the quality of the coal is good. Thus, as Dr. Jowett[4] wrote :—

'Although the destruction that has taken place is regrettable, the prospects of reasonably good coal occurring in quantity in a region where this phenomenon is frequently met with are favourable.'

Coal in Raniganj series.

Mr. Hughes noted four seams westward of Rikba: that of Balia (23° 48′: 85° 16′), early seen by Mr. Williams; others in the Barki *nala* south-east of Tandwa; that of the Gonda *nala* at the Raham crossing; those near Ganeshpur; and those of the Chati *nala* west of Hesalong (23° 40′: 84° 57′). Dr. Jowett[5] discusses these coal seams of the Raniganj series and his final opinions of these coal measures is worth quoting. He wrote (page 131) :—

'Judging from the outcrops, there are very few coal seams of workable thickness in the Raniganj stage, although outcrops of coal or carbonaceous shale are

[1] *Op. cit.*, pp. 300-312.
[2] Hughes, *op. cit.*, p. 309.
[3] Jowett, *op. cit.*, p. 47.
[4] *Op. cit.*, p. 38.
[5] *Op. cit.*, pp. 128-132.

frequently met with. The contrast with the Barakar stage in this respect is so striking as to afford some justification for the assumption that the Barakar rocks are the coal measures of the Karanpura coalfields, and although it is to be hoped that the possibilities of coal in the Raniganj rocks will not be lost sight of, it would undoubtedly be unwise systematically to explore them for coal until the resources of the Barakar rocks have been fully ascertained.'

Raniganj coal measures, evidently corresponding to the Sitarampur coal measures of Raniganj and the Murulidih coal measures of Jharia, occur in a small outlier along the faulted boundary of the South Karanpura coalfield but no coal seams have been found. By far the larger part of this area, shown on Dr. Jowett's map as Raniganj stage, corresponds with the Ethora sandstones of Raniganj and the Mahuda sandstones of Jharia, and, as recognised by me, belongs to the Barren measures of the Damuda strata in the Jharia coalfield.

South Karanpura : quality of coal in Barakar seams.

In connexion with analyses of coal from the cores of borings, it is now fully understood that the true quality is appreciably better than the core would suggest. This is because the bright, brittle coal is usually lost in boring, and so some of the good coal is not included in the core sample. This is a factor of importance in proving any coalfield and more particularly in India. Now Dr. Jowett[1] states that the lowest Barakar seams (under the Argada thick seam) vary in thickness from eight feet to 19 feet, but thin out northwards. He gives four analyses, presumably of four separate seams :—

—	1	2	3	4
	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Thickness of sample	11 6	7 9	8 10	8 4
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	2·88	2·18	4·54	1·86
Volatile matter	24·53	22·38	27·93	28·72
Fixed carbon	48·33	45·46	43·55	46·68
Ash	24·26	29·98	23·98	22·74
Phosphorus	0·28	0·20	0·28	0·35
Sulphur	0·95	1·08	0·73	0·85

[1] Pp. 103-104.

Samples 1 to 4 from a pit in the Argada seam are given by Dr. Jowett as having the following composition, but as a rule the coal as mined, is superior as seen in analyses 5 and 6 :—

——	1	2	3	4	5	6
	Ft. in.	Ft. in.	Ft. in.	Ft. in	Ft. in.	Ft. in.
Thickness of sample.	8 3	8 6	8 6	5 0	..	..
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture .	2·34	1·56	2·00	1·40	4·15	6·10
Volatile matter	26·54	31·16	27·00	31·30	32·85	31·88
Fixed carbon .	53·91	50·42	54·49	48·34	50·85	54·37
Ash . .	17·21	16·86	16·51	18·96	16·30	13·75
Phosphorus .	0·07	0·11	0·20	0·095	..	..
Sulphur . .	0·76	0·68	0·82	0·71	..	..
Calorific value (calories).	..	..	..	..	6,646	6,766

According to a large core-drill sample, to the bottom of the seam at 463½ feet, (thickness given as 69½ feet, therefore top of seam at 394 feet) the lower thick seam at Sirka (presumably the same as the Argada seam) was given in a report by Dr. E. Spencer as :—ash 18·4, moisture 1·49, volatiles 31·11, fixed carbon 49·0, sulphur 0·8 per cent., and the calorific value as 6,420 calories. The ash analysis is given as below :—SiO_2 9·98 per cent, Al_2O_3 6·54, Fe_2O_3 1·36, CaO 0·26, MgO 0·24, sulphur 0·01 and phosphorus 0·05 per cent.

Analyses of the Sirka upper seams are given by Dr. Spencer as below. Top depth from surface 261 feet, thickness of coal 30 feet, thin parting of one foot, bottom seam 24½ feet, depth to base of seam therefore 319½ feet.

——	Upper 30-foot seam.	Lower 24½-foot seam.
	Per cent.	Per cent.
Moisture	1·91	1·36
Volatile matter	31·19	31·07
Fixed carbon	51·55	52·81
Ash	15·35	14·76
Ash expected on working	14·7	14·5
Sulphur	0·65	0·91
Calorific value	6,525 calories.	6,600 calories.

The nature of the ash from these samples of the Upper and Lower Sirka seams, of which the proximate coal analyses are shown above, were found to be :—

—	Upper 30-foot 15·3 per cent. ash.	Lower 24½-foot 14·7 per cent. ash.
SiO_2	8·56	8·66
Al_2O_3	5·37	4·62
Fe_2O_3	1·04	1·26
CaO	0·31	0·15
MgO	0·06	0·02
P	0·09	0·05
S	0·01	0·02

Analyses of the seams higher in the Barakar series given below have been very kindly supplied by Messrs. Bird and Co., through Dr. E. Spencer. He states that that the Lower Sirka seam is now referred to as the *Argada seam.* In the Sirka area this Argada seam is 83 feet 8 inches thick and, exclusive of bands, is passed by the Grading Board as first grade quality. The analysis is given as :—

	Per cent.
Moisture	3·60
Ash	14·94
Volatile matter	33·12
Fixed carbon	48·34
Calorific value	6,553 calories.

In the case of the *Sirka seam* or as it was called, the Upper Sirka seam the quality of 18 feet in lower section (43 feet 8 inches down to 62 feet 2 inches and excluding a six-inch band at 58 feet) is indicated by the following analysis :—

	Per cent.
Moisture	3·55
Ash	11·70
Volatile matter	32·55
Fixed carbon	52·20
Calorific value	6,905 calories.

An upper section of 5 feet 10 inches (from 28 feet 8 inches up to 22 feet 10 inches) the quality of the *Sirka seam* is given by the analysis below :—

	Per cent.
Moisture	3·38
Ash	11·39
Volatile matter	33·44
Fixed carbon	51·79
Calorific value	6,950 calories.

And a still higher section of 10 feet 10 inches from 21 feet 10 inches to 11 feet (from the top) of this *Sirka seam* analysed as follows :—

	Per cent.
Moisture	3·60
Ash	11·82
Volatile matter	31·80
Fixed carbon	52·78
Calorific value	6,930 calories.

In an adjoining area, the Sirka seam has been identified as the *Gidi seam* which is 40 feet thick. The lower 33 feet of this seam yielded the following analysis :—

	Per cent.
Moisture	3·20
Ash	14·35
Volatile matter	31·38
Fixed carbon	51·07
Calorific value	6,671 calories.

The upper ten feet of this (33-foot) section was found to be better, the analysis giving

	Per cent.
Moisture	2·82
Ash	12·56
Volatile matter	30·80
Fixed carbon	53·82
Calorific value	6,847 calories.

Among the higher seams in the South Karanpura coalfield, the following, in order upwards, are of interest, as regards their quality from the accompanying analyses :—

The six-foot *Bhurkunda seam* (also known as the Lower Semana seam) shows :—

	Per cent.
Moisture	5·72
Ash	12·53
Volatile matter	33·39
Fixed carbon	48·36
Calorific value	6,497 calories.

The *Semana seam* (sometimes known as the Upper Bhurkunda seam or as the Upper Semana seam) which in its working section of ten to 11 feet is good, selected grade, shows :—

	Per cent.
Moisture	5·28
Ash	11·63
Volatile matter	31·73
Fixed carbon	31·36
Calorific value	6,352 calories.

The *Kurse seam* of roughly 16 feet is also worked at Bhurkunda colliery, the section extracted is about 8 feet 4 inches, and this shows :—

	Per cent.
Moisture	6·66
Ash	12·21
Volatile matter	30·98
Fixed carbon	50·15
Calorific value	6,508 calories.

Details are not available of the *Saunda seam*, but the ash content of a sample taken across the thickness of the seam was as low as 12·6 per cent.

The following analyses of the Upper Semana and Kurse (near surface) seams at Bhurkunda colliery have been kindly supplied by the Chief Mining Engineer, Railway Board :—

——	Upper Semana.	Kurse.
	Per cent.	Per cent.
Moisture	6·00	10·57
Ash	11·50	13·28
Volatile matter	33·20	30·33
Fixed carbon	55·30	56·39
Calorific value	6,429	6,428 calories.

The output of coal from the eastern end of the South Karanpura coalfield since 1924, when communication was established by the Gomoh-Daltonganj branch of the E. I. Rly., is given below :—

Production of coal, South Karanpura.

Year.	Tons.	Year.	Tons.
1924	..	1929	467,127
1925	13,354	1930	482,141
1926	123,667	1931	461,678
1927	262,014	1932	409,566
1928	390,493	1933	343,876

CHAPTER 9.

COALFIELDS OF BIHAR—*concld.*

COALFIELDS OF PALAMAU.

General.

There are three separate areas in which coal-bearing Damuda strata occur in the Palamau district, in the Province of Bihar and Orissa. These are the Aurunga, Hutar and Daltonganj coalfields. Coal appears to have been discovered in the North Koel valley as far back as 1779 as the word 'cole mine' appears on J. Rennell's map (No. VIII), dated 1779 (made 1778-79), of the 'Conquered Provinces of the South of Behar'. It is also marked on Arrowsmith's map of 1804. The exact locality shown on the map agrees with the position of coal outcrops in the Thongwa *nala* south of the village of Hutar (23° 49′ : 84° 3′), which is itself largely on Talchir rocks. Attention was drawn to the occurrence of coal in the Palamau area in 1827 by Mr. A. Prinsep, and these fields were examined about 1830 by Capt. Sage. The Hutar site was visited eariler (1829) by Capt. Franklin, who also knew of the coal in the Daltonganj field discovered two years before by Mr. Prinsep.[1] Mr. J. Homfray[2] reported on the Palamau coalfields in 1837.

In those early days attempts were made to work the coal in the Daltonganj field; these efforts were largely due to the enterprise of a Mr. Taylor from 1844 to 1848 and subsequently to the Bengal Coal Company, who are still interested in that and in the Hutar field. Communications were bad, and it was thought that the Son and North Koel rivers might be used. Several geologists have visited the Palamau fields since the visit of Mr. David Smith in 1856 and the wrecking of Rajhara colliery during the Indian mutiny of 1857. The most complete published reports are those of Mr. T. H. W. Hughes on the Daltonganj field[3] and of Dr. V. Ball on the Hutar and Aurunga coalfields.[4] These fields have since received careful attention,

[1] *Gleanings in Science*, I, Pl. 78; II, pp. 217, 219 and 220.
[2] Coal Committee's Report for 1845, p. 159, (1846).
[3] *Mem. Geol. Surv. Ind.*, VIII, p. 325, (1872).
[4] *Op. cit.*, XV, pp. 1-127, (1878).

but mining has continued in a small way although many efforts were made to develop it on a larger scale. In 1901 Daltonganj was connected with the main line of the East Indian Railway at Son East Bank, and after 1927-28 a chord line south and east through Latihar (23° 43′ : 84° 27′) was continued through the Karanpura and Bokaro coalfields. The Palamau coalfields are thus in a far better position for export purposes than ever before. Some few years ago a new colliery was opened near Harilong (23° 50′ ; 84° 5′) in the Hutar field, but as the coal trade is bad everywhere at present it is not possible to say whether the decreasing output may not lead to its extinction. The production from the Palamau coalfields since the Central Coalfields Railway was opened has been as follows :—

——	1926.	1927.	1928.	1920.	1930.	1931.	1932.	1933.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Aurunga . . .	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*
Hutar . .	*Nil.*	709	205	357	195	*Nil.*	*Nil.*	*Nil.*
Daltonganj . .	9,757	*Nil.*	929	1,522	1,569	411	*Nil.*	*Nil.*

The production from the Daltonganj coalfield is given in full in the section dealing with that field.

Aurunga Coalfield.

The Aurunga river which flows north-westwards through this coalfield and gives it its name joins the North Koel about eight miles south-east of Daltonganj (24° 2′ : 84° 4′). Dr. Ball[1] who appears to have named the field, recognised an area of 97 square miles of Gondwana rocks, made up as follows :—

	Square miles.
Mahadeva series	14·8
Panchet series	10·3
Raniganj series	8·8
Barakar series	58·5
Talchir series	4·5

This field has been recently (1927-28) re-surveyed by Dr. J. A. Dunn, who found that the area of Raniganj rocks was probably slightly larger, at the expense of the Panchets, than is indicated in Dr. Ball's geological map.

[1] *Mem. Geol. Surv. Ind.*, XV, p. 55, (1878)

The Aurunga coalfield is situated within 23° 42′ and 23° 52′ north latitude and between 84° 43′ and 84° 17′ east longitude.

Location.

Almost the whole area is in flat to gently-rolling country, with a few hills with scarped sides marking the outliers of the Mahadevas. Its eastern limit is about five miles west of the western end of the North Karanpura field, and even there a small outlier of Barakars lies in this interval at the watershed (about 23° 46′ : 84° 45′). The entire drainage is into the Aurunga river and so by the North Koel into the Son; the Aurunga coalfield is thus outside the catchment of the Damodar river. Yet it is evident that this field was an integral part of the Gondwana sediments which form the Damodar Valley coalfields.

Both Dr. Ball and Dr. Dunn have recognised the same strata as are found in the Karanpura and Bokaro fields, with the exception

Geology.

of the Middle Damudas, or so-called Ironstone shales. Their maps show that the Talchirs only peep out in places, and that in several cases the Barakars overlap the Talchirs on to the basement Archaean rocks. It seems to be somewhat difficult to mark off the Raniganj beds from the Barakars and to separate these from the Panchets. In mapping Dr. Dunn finds it satisfactory to regard as Panchets only those strata in the higher beds with mottled red clays. It is a question whether the lower beds without coal are Raniganj and not Barren measures, as all the evidence in the Damodar valley indicated conformability above the Barakaras, and unconformability below the Raniganj. This may help to explain other features of overlapping in this field. The Mahadevas appear to rest discordantly on the rocks below and lie directly on the Barakars in the western part of the field.

Dr. Ball[1] gave the thicknesses of the several series as follows: – Talchirs, 300 feet; Barakars, 1,500 feet; Raniganj, 1,000 feet; Panchet, 700 feet; and Mahadevas, 1,000 feet. These must be maximum thicknesses, as the Panchets and Raniganj series are wanting in the west. The field is sliced by four or five important faults; some of these trends north-west to south-east and have all the characteristics of a lateral dislocation, but its structure is evidently more complicated. The most arresting feature of the

[1] Manual, Vol. III, Economic Geology, p. 85, (1881).

Aurunga coalfield is the apparent absence of any intrusive rocks—either dolerites or mica-peridotites, but their non-discovery may be due to weathering and to insufficient development.

Quality of the coal.

Dr. Dunn states that the area '.... is described as a "coalfield" because it consists of Lower Gondwana beds which contain a few rare coal bands. But as a producer of coal the field is not likely to have any valuable mining future. The seams observed S. E. of Jagaldaga (23° 44′ : 84° 36′), and in the vicinity of Rajbar (23° 47′ : 84° 39′), and also near Tubed (23° 49′ : 84° 34′ 30″), although up to 40 feet thick, are of poor shaley coal. The thick seams consist largely of carbonaceous shale and the proportion of coal across their width is not high........apparently none is of first class quality.'

Dr. Dunn gives the following analysis of a sample of coal taken from a 40-foot seam in the quarry (vertical section sample over ten feet) near the main road bridge (23° 43′ : 84° 36′) over the Bagdagga *nala* between Chandwa and Lathihar :—

	Per cent.
Moisture	10·35
Volatile matter	27·81
Fixed carbon	26·43
Ash	35·41

which shows it to be practically worthless. And Dr. Ball's data in this connexion shows no better workable coals in the Aurunga coalfield.[1] Those analyses (from near Rajbar, 23° 47′ : 84° 39′; and from near Tubed, 23° 49′ : 84° 34′ 30″) are given below :—

Seams.	Rajbar.		Tubed.	
	Top.	Lower.	Top (12-foot).	Lowest.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	8·4	7·0	6·2	6·8
Volatile matter	28·6	26·2	28·6	29·0
Fixed carbon	33·0	38·4	30·6	38·6
Ash	30·0	28·4	34·6	25·6

Dr. Ball also mentions a thin (1 foot 6 inches) seam in the Raniganj series in the Sabanu *nala* about (23° 45′ : 84° 36′) which is of interest but no value, as it has 25 per cent. of ash and a moisture content of 5.

[1] *Op. cit.*, p. 111.

In view of the above analyses and of Dr. Dunn's recent examination of the Aurunga coalfield, the figures given by Dr. Ball[1] of the quantities of coal in the Rajbar 12,000,000 tons, Tubed 3,000,000 tons, and Jagaldaga 5,000,000 tons seams which total 20,000,000 tons are of very little practical value. The high percentage of ash in these coals is bad enough, but as the moisture content also averages more than five per cent. the coal can be of little use, except perhaps as powdered fuel in cement-making, where the ash will be utilised in place of clay. But this complete utilisation of the coal for its heat and ash as a reason for opening up this coalfield is an aspect which is not likely to receive consideration for many years.

Reserve of coal.

Hutar Coalfield.

As has already been stated, the occurrence of coal in the North Koel valley was known as early as 1779. The coalfield was finally named the Hutar field by Dr. V. Ball[2] when he mapped it in 1877-78 and chose the name of the village (Hutar; 23° 49′ : 84° 3′) where the first discovery was made. The field lies about 12 miles west of the western end of the Barakars of the Aurunga coalfield. It is placed exactly on a prolongation of the belt of country, in which the coalfields of the Damodar valley and the Aurunga river are situated. The area of the Hutar coalfield was estimated by Dr. Ball as roughly 78½ square miles made up as follows :—

	Square miles
Mahadeva series	14·1
Barakar series	57·0
Talchir series	7·5

As has been noted by Dr. Dunn in his recent re-survey of this area, no Raniganj or Panchet series of strata have been found. The Mahadevas occur only in the western part of the field, lying unconformably on the Barakars, and these coal measure strata (Barakars) overlap the underlying Talchirs. In the Manual[3] Dr. Ball gives the thicknesses of the Gondwanas as Talchirs 300 feet, Barakars 2,750 feet, and Mahadevas 1,000 feet. Dr. Dunn estimates much smaller thicknesses of the

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[1] *Op. cit.*, p. 189.
[2] *Mem. Geol. Surv. Ind.*, XV, (1878).
[3] Vol. III, Economic Geology, p. 86, (1881).

Mahadevas and Barakars. Dr. O. Feistmantel[1] suggested from fossil evidence the presence of the Karharbari stage in this field; but the rocks near Nawadih (23° 49′ : 84° 1′) are not so confirmed by Dr. Dunn's mapping. He considers the rocks there as truly Barakars, which may of course include the Karharbari stage in the Gondwana classification[2] adopted in recent years.

The field is traversed by a strong east-to-west fault through Tatta Balbal (23° 45′ 30″ : 84° 1′), where a hot spring occurs. Other faults are seen along the north of the western end of the field. Igneous rocks are uncommon, but dykes of dolerite have been found between Chamardiha and Barwadih (23° 51′ : 84° 7′) in the Talchirs. Dr. Ball[3] thought that the trap dykes belong 'very possibly to an earlier period than the Deccan trap but which must, however, have been subsequent to the Talchir period'. He assigns no reason for this opinion and was evidently influenced by his work in the Rajmahal hills.

Coal seams.

The field was examined by Dr. Saise in 1890 and recently by private enterprise by boring. Dr. Dunn who has seen the field since, takes his type section along the Deori *nala*, which traverses the Barakars in the eastern part of the field and notes five seams of coal and shaly coal (Nos. 1, 2, a chance seam, 3 and 4). No. 1 is 12 to 24 inches thick; No. 2 three feet; the chance seam is about 12 inches; No. 3 is an eight-foot seam and No. 4, the top seam, is 12 to 33 inches thick. No. 3 is the only workable seam in this area. The Bengal Coal Company have put down several borings in this tract and found No. 2 a consistently good seam. They found No. 1 good also but not so thick throughout.

The Horilong Coal Company, working on the east side of Dhaja Hill (23° 49′ 30″ : 84° 5′), have been exploiting a 4-foot 6-inch seam, of which the ash percentage is low but the moisture percentage rather high, in the part opened for extraction. The 'cole mine' seams in the Thongwa *nala* south of Hutar consist largely of carbonaceous shale. The Bengal Coal Company have proved part of the area between the Saphi *nala* and Sindharow (23° 48′ : 84° 3′) along the North Koel river, and found three fairly persistent seams—Nos. 2, 2A and 3—corresponding to those of the Deori *nala*.

[1] *Pal. Ind.*, Ser. XII, Vol. IV, Pt. 2, p. 12, (1886).
[2] *Mem. Geol. Surv. Ind.*, LVIII, p. iv, (1931).
[3] *Op. cit.*, p. 49.

South of Nawadih the coal seams are more in evidence than elsewhere in the field, the area includes the tributaries into the Saphi, from the north and north-west, up to the line Nawadih to Bijka (23° 47′ : 83° 57′). Here four seams are present—bottom four feet, next above eight to 12 feet, third five to six feet, and the top about four feet (in the Chhapra *nadi*). Further west it is not easy to correlate the seams, owing to the faulting and the fact that in the stream sections the thicknesses are different.

Quality of coals.

Dr. Dunn quotes several analyses of the coals from the seams recognised by him in mapping, and from bore-hole records, kindly lent by the Bengal Coal Company, of the areas Deori *nala*, Koel river above Sindharow, and the main Nawadih-Bijka seam :—

——	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value.
	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Deori *nala*—					
No. 4	11·72	27·6	51·97	8·69	5,844
No. 3	11·42	31·33	47·37	9·88	5,398
No. 2	8·40	31·85	48·95	10·80	6,032
No. 1	8·83	34·10	47·79	9·28	5,778
Koel river—					
No. 3	6·33	24·59	49·23	19·85	5,461
No. 2 A	9·08	24·92	54·03	11·97	5,669
No. 2	8·32	23·60	46·26	21·82	4,820
No. 1	6·54	26·71	42·90	23·85	4,747
Bijka area Main . .	8·60 4·16	22·35 26·59	53·25 59·95	15·80 9·30	5,654 6,510

Many of these analyses are of bore-hole samples and support those given by Dr. Ball.[1] He was chiefly impressed by the eight-foot seam in the Deori (Dauri) river south-east of Horilong, by the eight-foot seam in the Hudurparewa (Hurtah) stream below Tiharo (Toleh ; 23° 49′ : 84°), and the 13 feet 8 inches seam in the Saphi (Supahi)

[1] *Op. cit.*, p. 111.

river near Binda (23° 44′ : 83° 53′), in the extreme south-west corner of the field. He was most impressed by the seam in the *nala* below Tiharo—the average of two specimens from there giving him on analysis moisture 6·3, vol. matter 22·9, fixed carbon 57·5 and ash 13·3 per cent. (a first grade coal).

Dr. Ball wrote that it was futile to attempt any estimate of the millions of tons of coal possibly contained in the above three seams.

Reserves of coal.

Dr. Dunn, confining his attention to two seams only (No. 2, and perhaps 2A, and No. 3), in the area between the Deori and the North Koel above Sindharow, each about 4 feet 6 inches thick over an area of four square miles, arrives at a total of 16,000,000 tons in each. It is evident that this is but a fraction of the area in which attractive seams have been found, although their continuity has not yet been well established. Nevertheless, the existing railway facilities render the exploration of the Hutar coalfield distinctly attractive.

Daltonganj Coalfield.

The name was originally the Palamow coalfield, but was changed to the Daltonganj coalfield by Mr. T. W. H. Hughes[1] as more appropriate—being just north of the town of Daltonganj (24° 2′ : 84° 4′). Coal was first worked in this area in 1842 up to 1848, and then later by the Bengal Coal Company, whose colliery at Rajhara was wrecked during the mutiny of 1857, and who have been working there in a small way with few interruptions since. Previous to 1901, when railway communication was established down the Son valley to the main line of the East India Railway, the coal was sent down the North Koel river by boat.

Although the area, in which Lower Gondwana rocks occur, extends for 50 miles from east to west, and is over eight miles wide

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north of Daltonganj, thus covering an area over 200 square miles, yet the larger portion of this is occupied by Talchirs. The remainder of the area, roughly 32 square miles, is covered by Barakar coal measures. The plant fossil evidence was regarded as indicative of a Karharbari horizon for the seams about Rajhara, where a thick seam of 29 feet occurs. No younger rocks, except intrusive trap, have been found in this field.

[1] *Mem. Geol. Surv. Ind.*, VIII, p. 329, (1872).

The trap is that of a dolerite dyke seen in the Jinjoi *nala*, about the fords above Basdah (24° 8′ : 84° 9′). No mica-peridotite has been met with in working, but a deep boring near Rajhara (24° 10′ : 84° 3′) appears to have found a coal seam with *jhama* like coal. This boring is 450 feet and shows 14 seams of from six inches to five feet of coal.

Most of the workings have been about Rajhara and Pandwa (24° 10′ : 84° 4′) and Lohanda (24° 9′ : 84° 4′). Some of the oldest analyses show :—

Quality of coal.

—	Slaty coal.	Coal without lustre.
	Per cent.	Per cent.
Moisture	9·10	7·10
Volatile matter	37·40	36·40
Fixed carbon	52·10	54·10
Ash	10·50	9·50
Specific gravity	1·482	1·419

V. Ball[1] gives an average of four analyses better than the above while T. D. LaTouche[2], who carried out a boring exploration in 1891, found the quality very disappointing both in high ash and moisture.

Reserves of coal.

Mr. Hughes' original estimate of the coal reserves of the Daltonganj field were restricted to three square miles about Pandawa-Rajhara and to six feet of coal, *i.e.*, one seam; this gives 18,000,000 tons and allows, a deduction to 11,600,000 tons. Dr. Saise[3] made an estimate (evidently on the whole field) in 1890 and calculated 161,377,000 tons of coal with 11·7 per cent. ash. This was followed by Mr. LaTouche's examination in 1891, who took the Rajhara seam as averaging nine feet thick over one square mile in that area and arrived at a total of 9,000,000 tons. It is clear from his borings, which never exceeded 300 feet and seldom more than 150 feet, that no seams over seven feet were encountered in the larger area to the south. The

[1] Manual, Vol. III, Economic Geology, p. 87, (1881).
[2] *Rec. Geol. Surv. Ind.*, XXIV, pp. 138, 147.
[3] R. R. Simpson, *Mem. Geol. Surv. Ind.*, XLI, p. 59, (1922).

prospects therefore look unattractive, but this judgment cannot be considered as final.

Production of coal. The production of coal from the Daltonganj field is given below :—

Year.	Tons.	Year.	Tons.
1858	..	1882	No information.
1859	1,052	1883	,,
1860	1,135	1884	,,
1861	1,224	1885	,,
1862	1,607	1886	,,
1863	No information.	1887	2,500 (average)
1864	,,	1888	2,500 (average)
1865	,,	1889	2,500 (average)
1866	,,	1890	2,000
1867	,,	1891	No information.
1868	,,	1892	,,
1869	,,	1893	,,
1870	,,	1894	,,
1871	,,	1895	..
1872	,,	1896	..
1873	,,	1897	..
1874	,,	1898	..
1875	,,	1899	..
1876	,,	1900	707
1877	,,	1901	3,881
1878	,,	1902	19,352
1879	892	1903	33,557
1880	No information.	1904	50,517
1881	,,		

Year.	Tons.	Year.	Tons.
1905	71,294	1920	39,113
1906	86,768	1921	36,590
1907	81,873	1922	31,933
1908	96,391	1923	11,815
1909	84,290	1924	4,691
1910	84,996	1925	17,274
1911	70,662	1926	9,757
1912	71,917	1927	*Nil*
1913	85,345	1928	929
1914	81,680	1929	1,522
1915	85,785	1930	1,569
1916	76,298	1931	411
1917	79,627	1932	*Nil.*
1918	81,816	1933	*Nil.*
1919	63,250		

CHAPTER 10.

COALFIELDS OF ORISSA.

COAL IN TRIBUTARY STATES.

Mayurbhanj Coal.

A specimen of coal sent to the Geological Survey Office was reported to have been obtained from an outcrop exposed for several yards in Mayurbhanj State, about 24 miles south of Maluka railway station in the iron-ore country. An analysis of the specimen gave :—

Production of coal.

	Per cent.
Moisture	1·06
Volatile matter	22·42
Fixed carbon	61·58
Ash (colour grey)	14·94
Specific gravity	1·38
Cakes strongly	

The appearance and the analysis of the coal so strongly resembles that of a Lower Barakar coal, like No. X seam in the Jharia coalfield, that it seemed probable, if the report was true, that an outlier of such rocks may exist in the Mayurbhanj State. There is no record of any such rocks there, and in view of the character of the coal the matter was worth following up, to satisfy the *bona fide* aspect of the discovery. This was done by Dr. J. A. Dunn in 1932. He visited the area and made very careful enquiries on the spot, but was unable to find any trace of coal bearing rocks in the places he visited. Nor was he able to secure any sample of coal. In fact the whole matter has the appearance of a hoax.

COALFIELDS IN THE MAHANADI BASIN.

Atgarh (Athgarh) Basin.

Lieut. M. Kittoe[1] reported that coal had been found near Sideshar Hill, about four miles west of Cuttack. The rocks of that neigh-

[1] *Jour. As. Soc. Bengal.* VI, p. 320, (1837).

bourhood had been seen by Dr. W. T. Blanford[1] who suspected them to be newer than the Damudas. The country was mapped by Dr. V. Ball[2] who found plant remains proving the strata to be of Rajmahal (Upper Gondwana) age.[3] He also noted the presence of a basalt dyke near Sideshar Hill, showing that here at least the intrusive is younger than the Rajmahal plant beds. As regards the possibility of finding coal Dr. Ball says:—

'..A basin of coal-measures, the edges of which have been overlapped, may possibly occupy the centre of the area, and it can only be in view of such a possibility that any exploration can be undertaken. ......exploration by boring, if undertaken, should be directed chiefly to the eastern central portion of the area........ and even in the station of Cuttack itself, borings might be made........ On the accompanying map I have marked the localities in which the borings might be made, the numbers indicating roughly the order of their relative importance. Nos. 1 to 5 would be the most important........ In conclusion, I wish to make it quite clearly understood, that the indications do not appear to me to be such as to justify any good hopes of success, and consequently I cannot recommend any further expenditure being incurred for exploration by boring or otherwise.'

Talcher Coalfield.

The earliest published report of the Tributary Mehals of Cuttack is that of A. Stirling[4], Esq., but the first mention of coal in this region was made by Lieut. Kittoe[5] who, however, was not very successful in his investigations. The Coal Committee for 1845[6] record the coal of Gopalpershad in Cuttack (Orissa), in the fields of Talchergurh (the Balajora *nala*, half a mile from the fort), and Hingole (15 feet in the Singra *nala*). The reports were seldom confirmed by actual discoveries of an encouraging character, and our knowledge of the occurrence of coal in the Talcher area was not increased until the field was mapped by Messrs. W. T. and H. F. Blanford and Wm. Theobald (Jun) in 1855-56.[7]

[1] *Mem. Geol. Surv. Ind.*, I, p. 68, (1859); *Rec. Geol. Surv. Ind.*, V, p. 59, (1872).
[2] *Rec. Geol. Surv. Ind.*, X, p. 63, (1877).
[3] *Pal. Ind.*, *Ser.* II, Vol. I, Pt. 3, p. 189, (1877).
[4] *Asiatic Researches of Bengal*, XV, p. 163, (1825).
[5] *Jour. As. Soc. Bengal*, VI, p. 320, (1837); VII, p. 152, and 679, (1838).
[6] Report dated 1846, p. 103.
[7] *See Mem. Geol. Surv. Ind.*, I, p. 33, (1856).

The Talcher coalfield, named after the State and town (20° 57′ : 85° 14′) of Talcher, lies in the valley of the Brahmani river, which discharges into the delta of the Mahanadi, north-east of Cuttack. The Gondwana rocks which comprise this field extend westward from near Ambapalas (20° 55′ : 85° 20′) to Rampur (21° 5′ : 84° 20′), a distance of nearly 62 miles, across Talcher, Angul, Athmallik and Rairakhol. The whole tract lies in the valley of Brahmani river, as distinct from that of the Mahanadi. The town of Talcher is now connected with the main Bengal Nagpur Railway from Calcutta to Madras at Nergundi station, 250 miles from Calcutta, and five miles south of Kapilas Road station. Nergundi is situated (north of the Mahanadi, four miles north of Cuttack). This branch line, of 64 miles of broad-gauge railway, was constructed to tap the coalfield immediately west of Talcher town. The area covered by the Gondwana rocks of the Talcher coalfield has been estimated at roughly 700 square miles.

Location.

The strata recognised by Blanford's work consist of Talchirs, Damudas (Barakars) and Mahadevas (?). The now well-known and important series at the base—the Talchirs —were here first studied in detail, and the evidence for their glacial origin was obtained in this area. These Talchirs are probably 500 feet thick. The Damuda series is estimated to be 1,800 feet thick and include the coal measures of the field. The overlying strata, referred to as Mahadevas, are computed at from 1,500 to 2,000 feet thick. They are possibly the equivalents of the Rajmahals in the Atgarh basin, but if there are no Upper Damuda and Panchet rocks in this field, a large stratigraphical break clearly separates the coal measures from these Mahadevas. The discordance below the so-called Mahadevas is indicated by the manner in which they lie directly on the Talchirs in the western part of the field, where no coal-bearing Damudas appear.

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The northern boundary of the Gondwana rocks is marked by a strong fault. A southern boundary fault is also present suggesting that the Gondwana rocks are preserved in a trough by these two lines of normal faulting. There are several small faults which traverse the strata in different lines of strike. No basaltic or other dykes are evident in the Gondwana rocks, although one such dyke is known in the Atgarh basin. The basement rocks of the area are varieties of gneiss of Archaean

Faults and structure.

age, and these are cut by dykes of granite and diorite of pre-Talchir age. The coal-bearing beds appear to lie in the lower, though not the lowest, part of the Damudas, which are easily recognised as distinct from the Talchirs below and the Mahadevas above. There seems no doubt at all that the Gondwana rocks represent a small part of an extensive spread of these rocks, which once continued both east and west. To the west, north of Sambalpur, the eastern edge of another large tract of Gondwana rocks indicates one area with which the Talcher outlier was once joined.

Coal seams.

In 1855 when this field was examined few exposures of coal were seen and samples from these—as at Gopalprasad (20° 58′ : 85° 3′) and from two seams near Patrapara—gave such disappointing results that the field was not considered likely to prove valuable. Between 1919 and 1923, however, Messrs. Villiers, Ltd., of Calcutta examined the field by boring and found two workable seams of coal under an area of about 11 square miles near Talcher. They have sunk shafts near Handidhua (20° 57′ : 85° 12′) in which (No. 1 Pit) five feet of coal was met with at 86 feet, 8 feet 6 inches coal at 114 feet, six inches coal at 129 feet and 12 feet 6 inches coal at 144 feet; and (No. 4 Pit) 4 feet 6 inches coal at 200 feet, six feet coal at 208 feet, five feet coal at 277 feet and 13 feet 3 inches coal at 258 feet. The lowest seams are thought to be the same in each shaft. As the distance is relatively small, it would appear that there is some variation in the strata associated with the above seams.

An article, 'The Development of New Coalfields in India[1]', mentions the two seams of nine feet (top) and 12 feet (bottom), in the proved part of the Handidhua area and west of Talcher town, as underlying 11 square miles and averaging 12·25 and 8·5 per cent. of ash respectively, but with upwards of ten per cent. moisture. The proved area has been divided into six blocks A to F from the east westward. Messrs. Andrew Yule & Co. choose the Talbera-Remua (Talabeda-Remuan) or A block; the Dalbera (Deulabeda) or B block was earmarked for the Bengal-Nagpur Railway; the Handidhua or C block was opened up by shafts by Messrs. Villiers, Ltd.; the Madras and Southern Mahratta Railway selected the Ghantapada-Rodhasar or D block, as well as the choice of the Dera or E block; while the Balanda-Hensamula or F block is to be dealt with later. Further west are other blocks (A) Lachmanpur; (B) north of (A) from

[1] *Capital*, (June 6th, 1929).

Hensamula to Anantabereni; (C) west of (A) from Jambubahali southwards. These have been bored, but not developed.

The area west of Gopalprasad has also been tested by borings at Gopalprasad (No. 2), Nisa (No. 22; 20° 56′ : 85° 1′), Kankrai (No. 17), Kosla (No. 24), Raigharan (No. 16) and other places, in the valley of the Tengra or Singhada Jhora. In the Gopalprasad, Raigharan, Kankrai and Kosla borings the coal is present in beds two feet or so, interbanded with carbonaceous shale or Shaley coal. But as these results agree fairly well with the record of the borings in the several proved blocks (A to F), immediately west of Talcher town, presumably the seams are similar.

Quality of coal.

In appearance the Talcher coals are dull and frequently shale-like, but dull banded coal with fusain abundant is also common; and these appearances at first suggest the coal to be worthless. Samples cut from prospecting shafts by Dr. Fermor from the Handidhua block, however, gave ash percentages ranging from about 8 to 15·7. Analyses of samples from the two seams are shown below :—

—	Nine-foot, Top seam, less three feet roof coal.	13-foot, Bottom seam, less four feet roof coal.
	Per cent.	Per cent.
Moisture	11·25	10·07
Volatile matter	31·31	34·64
Fixed carbon	47·35	45·08
Ash	10·09	10·21

In their letter regarding the above analyses Messrs. Villiers, Ltd., stated that the section of the 13-foot seam being worked (*i.e.*, nine feet) had a band with 22 per cent. ash about six feet from the floor, and, if this were removed, the total ash in coal for despatch could be reduced to 8·73 per cent.

Since then it has been found that the shale parting was only locally present, and, furthermore the roof coal is good enough to work, and is extracted in de-pillaring operations.

Samples taken by Dr. L. L. Fermor* (1923), Mr. J. Thomas, and the Colliery Superintendent of the Madras and Southern Mahratta

Railway** (1928) and analysed by the Government Test House, Alipore, gave the results shown below :—

—	Eight-foot, Top seam. *	**	12-foot, Bottom seam. *	**
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	11·71	11·14	11·33	11·53
Volatile matter . . .	30·54	31·14	35·65	37·27
Fixed carbon . . .	46·18	45·47	44·11	42·76
Ash	11·57	12·25	8·91	8·44
Calorific value in calories .	6,737	6,809	7,056	7,310

The coal is dull in appearance and much of it resembles lignite but without the woody structure evident. It is chiefly composed of durain with fusain conspicuous in the bedding planes. Vitrain is a distinctly rare component.

Picked specimens of the chief constituents of Talcher coal from material from the Handidhua pits gave the following analyses[1] :—

—	Vitrain.	Fusain.	Durain.
	Per cent.	Per cent.	Per cent.
Moisture	15·08	1·42	5·90
Volatile matter	38·59	20·90	34·42
Fixed carbon	45·76	75·44	52·83
Ash	0·57	2·24	6·85
Caking	Weakly.	*Nil.*	Poorly.
Specific gravity	1·329	1·485	1·373

The high moisture content of these Talcher coals renders them non-caking and must affect their heating value, if the moisture is not readily lost on exposure to the air. When the coal from the 12-foot seam was subjected to a practical test in locomotives, it proved

[1] *Mem. Geol. Surv. Ind.*, LVII, p. 83, (1931).

suitable both for mail and goods trains. In 1923 the first production of coal from the Talcher coalfield was 4,816 tons; and the output increased to 68,973 in 1930 and 104,600 tons in 1931 from the workings of the Talcher Coalfields, Ltd., colliery at Handidhua.

The calorific value of the lower (12-foot) coal is about 6,250 to 6,400 calories, while that of the top (eight-foot) coal is roughly 5,950 to 6,150 calories on undried samples.

Reserves of coal.

Although the total area, in which the coal-bearing beds is exposed, exceeds 200 square miles, the boring operations do not claim to have proved more than about 11 square miles, immediately west of Talcher town, in two seams of nine feet and 13 feet. These figures would give a total of 242,000,000 tons of coal in 11 square miles. If, as was the case previously, the working thicknesses are six feet and under nine feet respectively or, say, 14 feet, then the total will be less. This in 11 square miles gives 154,000,000 tons, not allowing for faults and bad ground and other losses, which may be 33·3 per cent., and so leaves a total of 100,000,000 tons in the bored area of the blocks over 11 square miles. Dr. Fermor states that the coal seams and associated sandstones vary somewhat rapidly in thickness; consequently, in estimating quantities, it will be dangerous to include in our calculations any ground except that reasonably close to bore holes. In calculating the reserves in the lower (12-foot) seam, he accepted as definitely proved an area of roughly four miles by half a mile and a total of 2½ square miles, and estimated 30,000,000 tons *plus* dip coal of one square mile and six feet thick, giving another 8,000,000 tons. As regards the top seam, he allowed a length of three miles by quarter of a mile with an average thickness of over eight feet, and computed 6,100,000 tons of coal. His estimates therefore were :—

Top seam	6,000,000 tons proved.
Bottom seam	30,000,000 tons proved.
Bottom seam	8,000,000 tons probable.
TOTAL .	44,000,000 tons.

Because the parting between the two seams varies only from 12 to 35 feet and includes another seam, Dr. Fermor thought the resulting structural unsoundness must lead to losses during working of 30 per cent., and so his calculations give 30,000,000 tons of available coal in the restricted area defined by him.

It must be stated, however, that the data secured since the pits were opened and the seams examined have allowed somewhat larger reserves to be included in the estimates. Mr. J. Thomas, for example, considers that the areas involved form a tract 11 miles long from east to west, and roughly 1½ miles wide to the east and 2½ miles wide in the west. His eastern area extends from Remua to near Dera; the central area from Dera westward for 2½ miles, and the western area four miles further west to Gopalpersad. His *proved* ground is seven miles long by one mile wide. He adds a *probable* coal strip, half a mile in width to the dip of the above; and he regards as *possible* in the western area a tract four miles by 2½ miles. His workable coal in both seams totals some 15 feet, and he permits a loss in working, etc., of 40 per cent. From these data we can compile the following estimated reserves:—

Proved reserves in eastern and central area	60 per cent. of 15 × 7 million tons or 63 million tons.
Probable reserves in eastern and central area	60 per cent. of 15 × 3·5 million tons or 31·5 million tons.
Possible reserves of coal in western area	60 per cent. of 15 × 10 million tons or 90 million tons.

A series of borings along a line, extending 4½ miles north and south just east of Gopalpersad, justify the extension of the calculations to include the possible coal in the western area. Borings at Hensamula show that there are two six-foot seams at shallow depths; and two seams of 17 feet and seven feet, at 339 feet and 366 feet respectively, were found in the Jambubahali borings; these with the 18-foot seam proved in the Lachmanpur boring supply evidence for the *probable* reserves of the central area. Mr. Thomas has drawn attention to the low (small) specific gravity of the Talcher coal, which, if correct, will affect the estimates of quantities; but, as he has made a 40 per cent. allowance, the above figures may fairly represent the expectations of the Talcher coalfield. However, remembering that the Warora Colliery (Chanda district, Central Provinces) got into difficulties in endeavouring to work two seams at the same time and had to be abandoned, it is likely that the utmost care will have to be exercised, if the above expectations are to be realised. It is, therefore, of interest to record that the present system of working at Talcher is to set out large pillars when developing the lower seam, and to eventually de-pillar the top seam completely before reducing

the size of the pillars in the lower seam (below). Even this mode of extraction has not been found sufficient in the Jharia coalfield according to the opinions of the Subsidence Committee. It seems safest in every way to extract the upper seam before developing the lower seam, but these are matters of opinion.

Production of coal. The production of coal from the Talcher coalfield has been as follows :—

Year.	Tons.	Year.	Tons.
1921	..	1928	38,237
1922	..	1929	47,505
1923	4,816	1930	68,973
1924	5,417	1931	143,312
1925	7265	1932	253,586
1926	13,371	1933	316,539
1927	23,316		

Rampur or Ib River Coalfield.

This is the eastern end of a large area of Gondwana rocks which crosses the north-eastern part of the Central Provinces and South Rewah. Originally this south-eastern tract of Gondwana rocks was referred to as the Gangpur field because some of it lies in Gangpur State, but the name was changed by Dr. V. Ball [1] to the Raigur and Hengir (Gangpur) coalfield. Dr. Ball's name was later modified to Raigarh and Hingir coalfield[2] and refers to the whole of the south-eastern part of the Gondwanas of the eastern tracts of the Central Provinces. The name Rampur [3] coalfield was substituted for the Raigarh-Hingir field by the Government of the Central Provinces, but the reasons given do not now apply.

The name Rampur [4] or Ib River coalfield is restricted to the extreme eastern tip of the area where it is traversed by the Ib river which shows a narrow band of Talchirs connecting the Talcher coal-

[1] *Rec. Geol. Surv. Ind.*, IV, p. 101, (1871).
[2] *Op. cit.*, VIII, p. 102, (1875).
[3] *Mem. Geol. Surv. Ind.*, XLI, p. 86, (1913).
[4] See geological map accompanying *Rec. Geol. Surv. Ind.*, X, p. 186, (1877).

field with that of the Ib river area north of Sambalpur (21° 27′: 83° 58′). As long as it is remembered that the Ib River or Rampur coalfield after the important village of Rampur (21° 47′ : 83° 56′) is a part of the Raigarh-Hingir field and belongs to the Mahanadi group of Gondwana outliers, there need be no confusion in discussing the Rampur field as that part in the Sambalpur district of the new province of Orissa.

Geology.

The basement rocks are the Archaean gneisses and metamorphic rocks of Gangpur, Bamra and Bonai. The Gondwana rocks include the basal Talchir series, Damudas and Mahadevas. The Damudas have been found as two recognizable series—the Barakar or coal measures below, and the so-called Hingir beds, which are probably the equivalents of the Raniganj series, but resemble the Mahadevas and are barren of coal seams. So far as we have fossil evidence the presence of the Hingir (Kamthi facies of the Raniganj) beds has been established, and the Mahadevas are assumed present above them. The area of the Rampur coalfield in the Sambalpur and Gangpur areas is of the order of 200 square miles, as against a total of over 750 for the whole Raigarh-Hingir tract of Gondwanas, as far as the longitude of the Kurket *nala* (83° 20′). The southern boundary of the Gondwanas is a strong north-throwing fault trending north-west through Rabo (22° 4′ : 83° 16′). No basalt or dolerite dykes appear to be present. The northern margin is irregular, but the town of Hingir evidently lies in a basin, as the Barakars show up all round the edges of the field—along the south boundary fault, in the Ib river on the east and round to the north boundary.

Exploitation.

In the years 1884-86 systematic boring was carried out under Dr. W. King's [1] charge in the Bagadia, Lilari, Baisandar and Dulunga valleys, when, owing to the poor character of the coal met with, attention was directed to the Mand river and Korba areas, further afield to the north-west. Ten years later in constructing the Bengal-Nagpur Railway bridge over the Ib river (21° 49′ : 83° 57′), a thick seam of coal and carbonaceous shale was encountered and this discovery led to further exploration by the railway company, but with unsatisfactory results. In 1900 the area was carefully examined by Mr. G. F. Reader[2];

[1] *Rec. Geol. Surv. Ind.*, XVII, p. 123, (1884); XVIII, p. 169, (1885); XIX, p. 210, (1886); XX, p. 200, (1887).
[2] *Mem. Geol. Surv. Ind.*, XXXII, p. 89, (1901).

he found the Ib river outcrop faulted, and another north to south fault (throwing down to the east) on the west side of the Ib river. This north-south fault brings the outcrop of the thick seam to the Lamtibahal vicinity, where Rampur Colliery (21° 49′ : 83° 55′ 30″) is situated.

Mr. Reader's work and the bore-hole records then available indicated that the beds dip gently westward. The boring at Dhaunramunda (21° 50′ : 83° 50′) showed three seams:—top seam 17 feet thick at 309 feet; middle seams ten feet at 471 feet and 3·5 feet at 504 feet; and lower seams 13·5 feet, nine feet and 5·75 feet between 644 and 690 feet; and a basal seam about four feet at 768 feet. The lower seams are correlated with the so-called Rampur and Ib river seams on each side of the north-south fault. The seam at Lajkura is thought to be the same as the Darlipali seam and thus is probably the horizon of the middle seams of the Dhaunramunda boring. The outcrop of the top seam is thus unaccounted for and must lie between Samda (21° 49′ : 83° 51′) and Darlipali (21° 46′ : 83° 52′) in the Lilari valley. Mr. A. N. Guise, Manager of Rampur Colliery, reports a seven-foot seam at 70 feet in a well about Katabaga (21° 48′ : 83° 56′), suggestive of a seam below the Rampur seam. If the north-south fault is west of Katabaga, this seam (Bungalow seam) may be above the Ib river seam and thus correspond with the Lajkura-Kudopali-Darlipali seam. The fault is, however, believed to be east of Katabaga.

Mr. Reader's advice was followed and, in 1909 the Hingir-Rampur Coal Company, Ltd., under the management of Messrs. Killick Nixon of Bombay, had established a colliery south of Lamtibahal, from which by 1910, 830 tons of coal were raised. Since the War the output of coal from the Rampur coalfield has varied from 30,000 to nearly 70,000 tons with an average of 40,000 tons annually. They have a second colliery near Lajkura practically on the outcrop of the next seam above the Rampur (Ib river) seam. The property taken up is just under five square miles and has been divided into six blocks, of which two—Nos. III or Katabaga (with Rampur Colliery) and VI or Lajkura (with the second colliery), have been opened up. It is evident that, if the coal is attractive, considerable further development can be carried out south and south-west along the outcrop of the seams, as shown on Mr. Reader's map (sketch plan) by Kudopali and Darlipali towards Lakhanpur (21° 46′ : 83° 46′).

The top seam, 16 feet at 309 feet in the Dhaunramunda boring, gave upwards of 30 per cent. ash, so that it may be considered as useless for present purposes. The basal seam of four feet from 768 feet in the same boring also showed an ash content above 30 per cent.; and a similar ash percentage was found in the seam met with in the Kudopali boring (of 1896) at 352 feet. On the other hand the Ib river seam near (1) the railway bridge and again (2) near Rampur yielded :—

Quality of coal.

	1	2
	Per cent.	Per cent.
Moisture	8·00	9·00
Volatile matter	20·90	24·30
Fixed carbon	52·20	54·90
Ash (buff)	18·90	11·80

More recent analyses of the thick coal from Rampur colliery show variations as below :—

	No. 2 Pit.	No. 5 Pit.	No. 6 Pit.
	Per cent.	Per cent.	Per cent.
Moisture	13·34	12·30	14·01
Volatile matter	31·65	35·73	36·59
Fixed carbon	55·70	49·23	49·61
Ash	12·65	15·04	13·80
Calorific value on dried sample in calories.	6,717	6,581	6,680

(Analyses by Govt. Test House.)

A typical commercial sample from this seam (Rampur), of which only the lower seven or eight feet are worked, yielded (on an *undried* sample)—moisture 2·50, volatile matter 30·25, fixed carbon 51·25, and ash 16 per cent. at Jamshedpur. This analysis indicates that the coal must lose moisture in transit and that the quality is better than is shown in the analyses above from pits 2, 5 and 6.

An analysis of the so-called Bungalow seam shows :—moisture 9·80, volatile matter 28·44, fixed carbon 48·96 and ash 12·80 per

cent. with a calorific value of 6,022 calories. This appears to be more attractive than the Rampur seam and, after slight exposure to lose moisture, should give a higher calorific value; the analysis supports the idea that it is lower than the Ib river or Rampur seam.

It is not possible to estimate the coal reserves in the whole of the area herein called the Rampur coalfield. Even the Rampur seam does not underlie the whole area and is missing between the Katabaga fault and the Lamtibahal *nala*. We can allow a computation of at least seven feet of workable coal in the Rampur seam (quality above), under an area of 20 square miles westward from the Lamtibahal *nala* and north of the Lilari *nala*. This would give a rough total of 140,000,000 tons of coal, probably all within a depth of 600 feet from the surface. Allowing 40,000,000 tons for loss there should be 100,000,000 tons of coal available between the Lamtibahal *nala*, the Lilari river, and the Bengal Nagpur railway line in the Rampur seam. The estimated reserve in the property of the Hingir-Rampur Coal Co., Ltd., taking two square miles of workable coal in a seven-foot seam, is roughly 14,000,000 tons, and making an allowance for raisings, etc., probably greater than 10,000,000 tons.

Reserves of coal.

Production of coal.

The production of coal from the Rampur (Ib River or Sambalpur: Rampur-Hingir) field has been as follows:—

Year.	Tons.	Year.	Tons.
1911	..	1923	50,796
1912	..	1924	49,445
1913	133	1925	45,410
1914	60,883	1926	29,272
1915	58,825	1927	26,895
1916	59,737	1928	31,623
1917	52,892	1929	36,774
1918	51,038	1930	37,719
1919	45,574	1931	31,225
1920	36,987	1932	19,498
1921	77,277	1933	22,036
1922	68,618		

Hingir Coalfield.[1]

This name applies strictly to that strip of Barakars in the Hengir (21° 57′ : 83° 42′)—now spelt Hingir—Zemindari of Gangpur State, Bihar and Orissa, which extends from Amatpani (22° 12′ : 83° 39′), south-east through Gopalpur (22° 3′ : 83° 42′) and Dulanga (21° 57′ : 83° 48′), to Rautakhand (21° 54′ : 83° 51′). It is the connecting link between the Rampur (Ib river) field and the Raigarh field (Kelo and Kuket area), and is only a fraction of what Dr. Ball termed the Raigarh-Hingir coalfield—which originally bore the name Gangpur coalfield, because it was here that the first discovery of coal in the Mahanadi drainage[2] was made.

The Barakars, which consist of white to buff sandstones, grits, and conglomerate containing occasional pebbles of red jasper, rest directly on the Archaean gneisses which appear along the northern edge of the field. The junction appears to be one of original deposition. To the south the Barakars are covered by the Hingir (Raniganj series) beds, which consist mainly of red sandstones and grits. The distance between Amatpani and Rautakhand is roughly 26 miles and the average width of the Barakars is nearly 1½ miles; the total area can thus be computed at about 40 square miles.

Coal outcrops were reported from the Jhajia *nala* near Ghogarpali (22° 5′ : 83° 39′) about a mile above its junction with the Baisundar *nala*. Coal also occurs at the confluence of these streams near Gopalpur and further down where the track crosses from Tiklipara (22° 4′ : 83° 44′) to the south-west; other outcrops occur along the Baisundar from Siarmal (22° 3′ : 83° 44′) to Kainsara (22° 3′ : 83° 46′), near Kirpsera (21° 59′ : 83° 47′), and near Dulanga (21° 57′ : 83° 48′) in the Dodaria *nala*.

Borings were carried out by Dr. King[3] in three places—at Rattansara (22° 4′ : 83° 40′), Gopalpur, and Bankibahal (22° 2′ : 83° 45′). Of these the first was able to prove a top 16-foot seam and two six-foot seams (three-foot partings between them) at 100 feet below. The Gopalpur bore found a 25-foot seam at 165 feet, about 100 feet below an upper six-foot seam. The Bankibahal boring proved three seams :—20-foot at 11 feet, four-foot at 34 feet, and ten-foot at 82 feet. It was not found possible to correlate these seams.

[1] In writing this section, I have used information supplied by Dr. M. S. Krishnan who mapped the metamorphics along the Barakar boundary in 1931.

[2] *Rec. Geol. Surv. Ind.*, IV, p. 101, (1871).

[3] *Op. cit.*, XIX, p. 216, (1886); XX, p. 200, (1887).

The samples taken from the borings were all very disappointing in their high ash percentage, and further exploration was discontinued. An outcrop near Rāttansara, of nine feet, gave from the lower four feet samples of fair quality coal. A section showing coal with shale partings, of an estimated thickness of 45 feet, is exposed on the left bank of the Baisundar, just above its confluence with a tributary north of Gopalpur. A specimen from the middle part of the section, collected by Dr. M. S. Krishnan, gave on analysis:—

	Per cent.
Moisture	4·24
Volatile matter	32·98
Fixed carbon	43·74
Ash	19·04
TOTAL	100·00

Specific gravity, 1·427; does not cake; ash white. A seam of about ten inches thickness in the upper part of the same section consists of a mixture of powdery red ochre and grains and thin layers of vitrain. An analysis of the vitrain gave:—

	Per cent.
Moisture	6·8
Volatile matter	32·62
Fixed carbon	59·64
Ash	0·94
TOTAL	100·00

Specific gravity, 1·346; does not cake; ash drab.

There seems to be no doubt that coal seams of workable thickness occur in the valley of the Baisundar south of Tiklipara, and it is a matter for further investigation whether bore-hole samples can be safely accepted as an index of the true character of the coal. It is known, however, that some prospecting work was carried on, some years ago, by the Rampur Coal Co. at the outcrops near Dulanga and Siarmal, but, from the fact that no further work was done since, it may be inferred that the results were not promising.

CHAPTER 11.

SON VALLEY COALFIELDS.

UNITED PROVINCES.

Mirzapur District.

On an earlier page, it was stated that no coal of economic value was known from any strata older than the Lower Gondwanas; but at various times during the past hundred years there have been reports of the discovery of coal in the area bordering the Son Valley on the north and extending westward from near Rhotasgarh (24° 34′ : 83° 55′) in Shahabad (B. and O.), through Bijaigarh (24° 26′ : 83° 12′) in Mirzapur (U. P.), and continuing to Bundelkhand (C. I.)—an area occupied by unfossiliferous Vindhyan rocks (Cambrian to Pre-Cambrian). These rumours received attention in several publications, the more important being those by Captain Franklin[1], George Osborne[2], H. B. Medlicott[3], F. R. Mallett[4], E. Vredenburg[5], besides other papers.[6] The following is taken from the last reference, in which Sir Edwin Pascoe, discussing these reports of coal in pre-Gondwana rocks in the area outlined above, states :—

'In every instance the beds referred to have proved to be one or other of the bands of black carbonaceous or pyritic shale which occur at the base of the Upper Vindhyans or in strata of the Semri series (Lower Vindhyans)....In fact no coal, recognisable as such, has been noted from any of the occurrences. The latest rumour of coal in the Vindhyans comes from the Bijaigarh shales in the scarp facing the Son valley a few miles west of Rhotasgarh.......The material is a carbonaceous shale of the following composition :—moisture 1·44 per cent., volatile matter 9·10 per cent., fixed carbon 12·28 per cent. and ash 77·1 per cent. The specific gravity of the shale is 2·407 .....'

It is, of course, too much to hope that such rumours will not recur, but it is hoped before a fresh report is spread that a trial will be made of the material discovered. It is a simple matter to weigh

[1] *Asiatic Researches*, XVIII, p. 104, (1833).
[2] *Journ. As. Soc. Bengal*, VII, pp. 839-849, (1838).
[3] *Mem. Geol. Surv. Ind.*, II, pp. 91-93, (1860).
[4] *Op. cit.*, VII, pp. 45 and 121, (1869).
[5] *Rec. Geol. Surv. Ind.*, XXXIII, p. 269, (1906).
[6] *Op. cit.*, LXII, p. 35, (1929).

a small quantity of the supposed coal and after burning it to collect and weigh the ash. As will be mentioned later when dealing with the coal occurrences of Madras, the rumour of the discovery of coal was kept alive for 30 years by a military officer unable to produce one pound of the coal which he persistently maintained existed in a particular locality. He was given the opportunity to produce the coal, borings were put down in the places he specified, yet on his final retirement from India, he persisted in his assertion that the place had been insufficiently examined.[1]

CENTRAL INDIA (SOUTH REWAH) COALFIELDS.

General.

The only coal-bearing strata of Lower Gondwana age which lie within the limits of Central India are those of Rewah State. They are outcrops of Damuda coal measures which appear from beneath the large spread of Upper Gondwanas of the Son-Mahanadi watershed in Chhattisgarh. It is as certain that the coalfields of the Damodar valley and those of Aurunga, Hutar, and Daltonganj were once part of the north-eastern portion of the Chhattisgarh-Rewah Gondwana basin, as it is that this region also connected south-eastwards, through the Rampur (Ib River) coalfield, with the outlier of coal-bearing rocks in the Talcher coalfield. It is true that the greater part of the Gondwana area of the Rewah-Chhattisgarh basin is covered by strata younger than the Barakar (coal measures) series, and that in a normal manner the Barakars should underlie them. This general conclusion is supported by the fact that the Barakars, and below them the Talchirs, are met with along the outer fringes of the younger rocks; also inliers of these Lower Gondwanas are found within the spread of Upper Gondwanas, where the upper strata have been removed by erosion. In the Central India or South Rewah tract, the following coalfields have been recognised:—

I. The Singrauli coalfield, with an area of nearly 900 square miles of Damudas, situated 24° 12′ and 23° 47′ north latitude and 82° 52′ and 81° 48′ east longitude on the borders of the Mirzapur district and south of the Son river.

[1] *Rec. Geol. Surv. Ind.*, XV, pp. 207-216, (1882).

this tract in 1840 by Captain Wroughton[1] and a colliery was working near Kota (24° 7′ : 82° 44′) in the Mirzapur district at the time of Mr. David Smith's visit in 1857.[2] The area was geologically examined by Mr. R. D. Oldham[3] between 1894-96. Mr. K. P. Sinor[4] has given a summary of the Rewa Coalfields in his report on the Mineral Resources of Rewa State. Finally in 1922-23 Dr. A. L. Coulson[5] visited this area with the survey party of the Central Indian Coalfields Railway. Mr. R. R. Simpson[6] mentions that coal was again extracted for a time in 1896 in the Kota vicinity of the Mirzapur district when about 1,000 tons were raised.

Coal occurrences.

Captain Wroughton stated that the Kota coal was 4 feet 9 inches thick and gave two per cent. ash, but it is thought that the coal analysed must have been a picked piece. According to Mr. D. Smith a seam of nine feet of clean coal occurs at Turah near Naunagar six miles west of Kota, and that a seam of 21 feet of coal was being quarried in his time (1857) near Pudri (possibly Parari) about 18 miles west of Kota. Mr. Oldham noted several coal localities and records seams of six feet near Ujehni and 5 feet 6 inches near Amlei. Mr. Sinor gives a list of coal seam outcrops, roughly, as follows:—

(1) An eight feet seam two miles north of Naunagar in the Ghuraoli hills (24° 8′ : 82° 39′) and east of the trigonometrical station of Ghuraoli.

(2) One seam near the boundary between Rewa State and the Mirzapur district, a mile south-west of Onrawa (24° 9′ : 82° 42′).

(3) Another seam three miles north-east of Tulda and 1½ miles south-west of Thurwa (24° 11′ : 82° 35′).

(4) One outcrop 2¼ miles south-west of Koelkut and 1½ miles south of Parari (23° 55′ : 82° 30′ 30″).

(5) One outcrop three-quarters of a mile west of Kachra (23° 52′ : 82° 31′ 30″).

(6) Another seam 2½ miles west of Chitouli (23° 53′ 30″ : 82° 32′).

[1] *Eng. Jour. Calcutta*, II, p. 340, (1859).
[2] *Sel. Rec. Govt. Ind.*, LXIV, p. 93, (1868).
[3] *Rec. Geol. Surv. Ind.*, XXVIII, p. 117, (1895); see also *Mem. Geol. Surv. Ind.*, XXXI, pp. 133-140, (1901).
[4] *Geol. Dept., Rewa State, Bull.* No. 2, p. 57, (1923).
[5] Geological Report, p. 46, (October, 1923).
[6] *Mem. Geol. Surv. Ind.*, XLI, p. 80, (1922).

(7) A seam in the stream near Amlei (24° 2′ : 82° 29′).
(8) One in the Bandha *nala*, half mile south of Ujehni (24° 10′ : 82° 25′).
(9) Shaly seam in feeder of Mohan river near Ubri (24° 9′ : 82° 20′).
(10) Shaly seam between Katdaha and Paraidol (24° 11′ : 82° 15′).

He states that the seams near Naunagar, Koelkut, Amlei and Ujehni are important.

Finally, Dr. Coulson discusses the coal outcrops seen by him. He mentions a six-inch seam near Majgama, said to be used at Lohjhar; a seam, of which 1½ feet is exposed, in the Bardia *nala* south-west of Naoriah; a 2-foot 9-inch seam (No. 22) in the Deora *nala* near its confluence with the Mohan river—the analysis of this coal showed moisture 8·68 per cent., volatile matter 30·27 per cent., fixed carbon 39·35 per cent. and ash 21·70 per cent., and it gave a calorific value of 5,123 calories (experim.); a seam (No. 24) of six to eight feet of coal, a mile east of Ujehni; a section showing several thin seams with one of 3 feet 6 inches under water, in a stream 2½ miles E. N. E. of Ujehni and one mile south-west of Manhari. He mentions Mr. Sinor's eight-foot seam two miles north of Naunagar, but found an 18-foot seam 1½ to two miles north of Naunagar, from which were taken two samples No. 31, 11 feet from top and No. 32, eight feet from top. He also visited the old workings near Kota, but could not secure a sample *in situ*. He found three feet of coal (No. 29) exposed three miles north-west of Amlia (Amlei ?) in the Amlia Ghat. He adds :—

'Of the seams that have been described, those of workable size are as follows :—Ujehni, 3′ and 6′ to 8′; Manhari, 3′ 6″ and others; Naunagar, more than 18′; Amlia, more than 3′; Parari (Sinor, more than 6′); and possibly Kota.'

Quality of coal. Dr. Coulson wrote of the seams : —

'As to quality, the Ujehni seams appear useless. The Naunagar outcrop is apparently the most promising seam in quantity and quality, though Sinor's seam at Parari looks promising. This Naunagar seam occurs about 4 miles north-east of the proposed station of Kuchuni on the northern of the two alternative routes of line B...... '.

Writing of the 18-foot seam 1½ to two miles north of Naunagar, Dr. Coulson states :—

'In this 18′ seam there were three bands of shale but the total thickness of these was not greater than 1′. The coal is composed of alternate layers of bright

and dull coal and its average quality appeared above that of the Singrauli coals already described.... '.

Analyses of the Singrauli coals, given or quoted by Dr. Coulson, are as follows :—

—	1	2	3	4	5	6	7
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture . .	6·28	12·00	15·37	7·37	5·68	2·08	4·60
Volatile matter .	26·62	28·51	30·17	26·35	28·14	8·72	26·00
Fixed carbon .	49·42	39·06	42·72	41·10	52·72	44·76	41·12
Ash . . .	17·68	20·43	11·74	25·18	13·46	44·44	28·28
Calorific value .	5,445	5,156	5,615	5,333	5,802	..	..
Caking . .	*Nil.*	*Nil.*	*Nil.*	*Nil.*	..	*Nil.*	*Nil.*

N.B.—Calorific value in calories (theoretical) :—

1. Sinor, Naunagar eight-foot, two miles north of Naunagar.
2. Coulson, Naunagar 18-foot, No. 31 (see above).
3. Coulson, Naunagar 18-foot, No. 32 (see above).
4. Coulson, Amlia Ghat three-foot, No. 29 (see above).
5. Sinor, Parari six-foot, 1½ miles south of Parari.
6 and 7. Unpublished analyses of Oldham.

From the above analyses, it is clear that the Parari seam (six-foot) is fairly attractive, and that the Naunagar seam (18-foot), if sampled foot by foot, may yield a good quality coal.

Reserves of coal.

It is certain that the Singrauli coalfield must contain a large quantity of coal, but the evidence so far does not show that the quantities of good coal are large. The coalfield is at present so inaccessible that it has not justified expensive exploration by extensive boring. However, the six-foot Parari seam and the 18-foot seam near Naunagar cannot be dismissed without some word in regard to reserves. If the six-foot seam mentioned by Sinor can be followed, the amount of coal per square mile is 6,000,000 tons in this unit of area ; and the 18-foot seam found by Coulson, if considered only 15 feet thick, will average 15,000,000 tons per square mile. Should the Central Indian Coalfields Railway be constructed on the B alignment modified to pass close to Naunagar and Amlia, both these seams will be within easy reach of feeder lines. At present the building of the through line from Daltonganj westwards is in abeyance, and the condition of the coal industry does not permit of any hope of the opening up of new coalfields of coal of the quality so far found in the Singrauli field.

Korar Coalfield.

The name Korar was given to this coalfield by Mr. T. W. H. Hughes[1] from the village of Korar (23° 37′ : 80° 53′) about seven miles north by east of Umaria. There appears to be a north-east fault separating the western part of the Umaria field from the eastern edge of the Korar field and having a downthrow to the south-east, so that on a north-east line there is a displacement of three miles between the exposed coal measures (Barakars) of these two fields. The area of the Korar coalfield is roughly 9½ square miles, with Talchirs overlying the metamorphic Archaean rocks to the south-west and a dolerite dyke-sill on the north and through the eastern half of it. Rocks thought to be Upper Gondwanas occur to the east and north, but it is possible those to the north may be representatives of the Raniganj series, if there is no great ' break ' or overlap of the younger formations in this vicinity. The reported occurrence of coal was brought to Mr. Hughes' notice about 1880, this was confirmed by Lala Hira Lal in December 1882, when he was mapping east of Tali (23° 38′ : 80° 49′).

There are six recorded outcrops of coal and carbonaceous shale in this field—those of exposures near Anchla, Dadraoni, Korar, Khaira, Jwalamukhi, and Barbaspur. Borings at Jwalamukhi (near the Barhua *nala* between Korar and Kotalwah) proved four seams of coal—eight-foot at 12 feet, four-foot at 23 feet, four-foot at 29 feet and eight-foot at 48 feet. From the outcrop of one of these seams a weathered sample yielded the following analysis :—

	Per cent.
Moisture	5·04
Volatile matter	12·56
Fixed carbon	65·48
Ash	16·92

Umaria Coalfield.

This is the smallest of the Rewah coalfields, with an area of only six square miles of coal-bearing Damuda rocks exposed. The name is derived from Umaria village (23° 32′ : 80° 51′) on the Umrar *nala*, a tributary of the Mahanadi, which joins the Son about 24° 5′ : 81°. About 1857 this area was first geologically examined by Mr. J. G. Medlicott[2] who considered all the rocks as Lower Damudas, includ-

[1] *Mem. Geol. Surv. Ind.*, XXI, Pt. 3, p. 26, (reprint 1925).
[2] *Op. cit.*, II, p. 171, (1860).

ing those now known as Jabalpurs. H. B. Medlicott crossed here in 1868-69 and noted the Talchirs north of Umaria. Mr. Hacket did not complete the survey in 1871-72, but left the impression that the coal occurred in the Jabalpur beds. Coal had been known here for several years before attention to it was drawn by Captain Osborne in 1860. So long as Hacket's opinion held it did not seem profitable to make any serious exploration for workable seams. However, under Mr. T. W. H. Hughes' orders the area was searched by Lala Hira Lal during the detailed surveys of 1879-80. He discovered plant fossils which proved that the coal measures were truly Lower Damudas (Karharbari to Barakar). This immediately gave a new aspect to the question of exploration, which was carried out by Mr. Hughes[1] himself, who, with the active assistance of Captain Barr, was able to open up the field by 1882; and since 1882, when Mr. Hughes was in charge, coal has been steadily raised from the pits put down in the Umaria coalfield. The annual production from the Umaria field during the last decade (1919 to 1923) has averaged nearly 120,000 tons. Up to 1900 the collieries were worked on behalf of the Government of India, but in that year they were handed over to Rewah State.

To the west the field is cut off along a north-east line, evidently by a fault which brings in the Lower Gondwanas to the south-east.

Geology.

West of the fault appear Archæan metamorphic rocks of the Lora ridge.[2] Talchirs occur to the south and south-west of the coal-bearing rocks, which in turn are covered by so-called supra-Barakars of possibly Raniganj age, but this has not been established. A narrow synclinal follows the margin of the west fault on the downthrow side along the same north-east direction. Away from the fault the strata have a gentle north-east dip. It was once thought that the coal measures corresponded with the Karharbari stage of the Giridih field. The most interesting fact relating to the Umaria coalfield was the discovery, in 1921, by Mr. K. P. Sinor, of marine fossils above the Talchirs and at the base of the Barakars in the Narsarha cutting of the Bengal-Nagpur Railway, about two miles west of Umaria station.

It has been shown that a slight 'break' separates the marine beds from the underlying Talchir boulder bed, and it is now accepted that the marine beds are conformably below the coal-bearing

[1] *Mem. Geol. Surv. Ind.*, XXI, Pt. 3, pp. 1-3, (reprint 1925).
[2] E. R. Gee, *Rec. Geol. Surv. Ind.*, LX, p. 399, (1928).

Barakars. It is presumed that an arm of the Permo-Carboniferous sea extended to Umaria just before the coal measures were laid down. Mr. Gee's work has proved that the supra-Barakars overlap the coal measures (Barakars) in the south-west corner of the field. As regards the coal-measures, Sinor[1] states that the field has six seams, four of which are workable.[2] These seams are :—

	Thickness.
No. I seam	4 feet 6 inches to five feet.
No. II seam	4 feet 6 inches to 7 feet 6 inches.
No. III seam	8 feet 6 inches to 13 feet.
No. IV seam	three feet to 4 feet 6 inches.

Of these Nos. II, III and IV were worked in the Khalesar quarries, and Nos. II and III in the quarries near Umaria. Nos. II and III are only worked in the mines of Umaria colliery from Pits 1 to 11, the only ones now in existence, many of the older ones are lying abandoned. The seams are numbered from the bottom upwards. No. I is the basal seam.

Quality of coal.

The following analyses of seams II and III are taken from Sinor's monograph [3]:—

Calorific value (calories).	Seam.	Moisture.	Volatile matter.	Fixed carbon.	Ash.
		Per cent.	Per cent.	Per cent.	Per cent.
4,893	No. II top . .	7·05	22·20	41·35	29·40
5,307	No. II bottom .	7·27	24·95	48·28	19·50
5,266	No. III top . .	7·36	25·06	47·89	19·69
4,599	No. III splint .	7·30	22·95	42·85	26·90
6,315	No. III bottom .	3·22	22·83	61·05	12·90

Recent analyses of the coal of the best seam are shown below :-

Section in No. III seam, No. 16 level, main dip north-east of No. 8 Pit, shows—

Roof.

11 feet { 3 feet 9 inches coal.
2 ,, 0 ,, splint coal.
4 ,, 3 ,, coal.
1 foot 0 ,, splint coal.

Floor

[1] Mineral Resources of Rewa State, p. 23 (1923).
[2] *See* also R. R. Simpson, *Mem. Geol. Surv. Ind.*, XLI, p. 76, (reprint 1922).
[3] *Op. cit.*, p. 24.

and gave the following proximate analyses :—

	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value.
	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Roof.					
11th foot	16·33	27·41	40·18	16·08	Worked out by Goutal's formula.
10th "	17·91	30·19	37·28	14·62	
9th "	16·15	27·88	43·17	12·80	
8th "	11·63	25·18	34·77	28·42	
7th "	9·70	20·15	28·59	41·56	
6th "	13·10	25·63	30·86	30·41	
5th "	16·20	33·87	38·41	11·52	
4th "	16·50	32·97	40·63	9·90	
3rd "	19·06	36·06	36·71	8·17	
2nd "	18·30	33·37	39·43	8·90	
1st "	Not taken floor coal left.				
Floor.					
10 foot	154·88	292·71	370·03	182·38	..
Average	15·49	29·27	37·00	18·24	4,936
	After deducting 6th and 7th bands.				
Average	16·51	30·87	38·82	13·80	5,128

A sample of this coal taken on 20th April, 1929, and analysed by the Government Test House, Alipore, gave—

	Per cent.
Moisture	14·31
Volatile matter	28·65
Fixed carbon	54·97
Ash	16·38
Calorific value on a dry basis	6,198

Production of coal.

The annual production of coal from the Umaria coalfield since the area was developed in is shown below:—

Year.	Tons.	Year.	Tons.
1881	..	1901	164,362 (Umaria and Johilla.)
1882	..	1902	171,538 (Umaria and Johilla.)
1883	..	1903	193,277
1884	2,100 (Central India.)	1904	185,774
1885	7,698	1905	157,701
1886	13,539	1906	170,292
1887	15,497	1907	178,588
1888	41,580	1908	155,107
1889	52,956	1909	121,496
1890	77,842	1910	130,400
1891	69,741	1911	143,558
1892	88,623	1912	149,921
1893	94,348	1913	148,978
1894	132,837	1914	152,906
1895	118,479	1915	139,680
1896	115,386	1916	200,285
1897	124,778	1917	198,407
1898	134,726 (Umaria and Johilla.)	1918	199,975
1899	164,569 (Umaria and Johilla.)	1919	182,141
1900	164,489 (Umaria and Johilla.)	1920	158,051
		1921	154,974
		1922	118,538
		1923	95,825

Year.	Tons.	Year.	Tons.
1924	104,124	1929	112,624
1925	102,936	1930	100,145
1926	108,109	1931	83,321
1927	135,120	1932	74,293
1928	101,327	1933	172,390

Reserves of coal.

In 1885 Mr. Hughes had written of the two chief seams as having a total average thickness of 20 feet in the proved area ($1\frac{1}{4}$ square miles) and assumed that this coal might be expected under an area of four square miles. This makes the total coal for this area as 80,000,000 tons, of which Mr. Hughes considered 55,000,000 tons as *available*. In 1902 Mr. R. J. W. Oates, then Manager at Umaria, estimated the total coal proved by the borings and shafts as 24,000,000 tons.[1] As the Umaria collieries have been at work for 50 years, and the seams have been exploited to an amount approaching six million tons with possibly a similar quantity left as pillars, nearly half Mr. Oates' total is accounted for. The fact that the opening of a colliery on the Khalesar side of the Umrar *nala* has been under consideration for the past few years shows that further development is contemplated in the near future. There can, however, be little doubt that the seams continue north-eastward under the red rocks of the supra-Barakars, but to greater depths. With the low dips prevailing, this northern tract should contain workable coal within reasonable depths, at a distance of at least a mile north of Umaria. Further, the tract north-west of Umaria, towards Chatan, also remains unopened and should contain workable coal. Taking, therefore, an area of six square miles, with eight feet of workable coal, we get a total of 48 million tons, and subtracting from this 12 million tons accounted for, and allowing a loss of one-third for the remainder, there is a future available supply of 24,000,000 tons.

Johilla River Coalfields.

Two areas of coal measure (Barakar) rocks occur in the valley of the Johilla river west and south of Pali respectively. Dr. Spils-

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 76, (reprint 1922).

bury[1] recorded the coal of this tract as long ago as 1846, Mr. Hughes[2] described these as the *north* and *south* areas respectively, and considered only the former as of economic value. He stated that the accident of a better position led to the development of the Umaria field. Borings were made as a precautionary measure in the north area of the Johilla field, and these led to the knowledge of a further and extremely valuable stock of coal land in this Johilla tract. The north Johilla River field covers an area of 11½ square miles, while that of the south area is only 3¼ square miles.

Geology.

An area of gneissic and granitoid rocks is seen about Ponri. On these rest the Talchirs at the base of the coal measures of the north area, and on these again lie the Barakars which are in turn overlaid by the Pali-Daigaon beds of Raniganj age. All the strata show more or less steady north dips at low angles, so that the coal measures can be at no serious depth under Pali and are probably easily accessible under Birsingpur railway station, about 18 miles south-east of Umaria railway station on the same line (Bengal-Nagpur Railway, Katni-Bilaspur branch). In Mr. Hughes' time borings proved two seams of coal—a top 17-foot seam and a lower six-foot seam—barely 20 feet below. The most notable outcrop is that at the junction of the Ganjra *nala* with the Johilla river, 1¾ miles west of Pali; another occurs above the confluence of the Marjada and Umarha *nalas*. In 1858 Mr. J. G. Medlicott had noted coal near Maliagura village.

The plant fossils found below the seam in the Johilla river (Ganjra *nala* junction) included two species of *Gangamopteris*, which suggested the horizon as being that of the Karharbari stage. The Ponri Archaean rocks lie north-west of the south area, with Talchirs between them and the coal-bearing Barakars, so that the dips are, in general, eastward. The Raniganj or supra-Barakar rocks of this area evidently overlap on to the Talchirs and appear to be faulted against the Ponri gneisses along a line trending north-east. Mr. Hughes has stated that no promising coal seams are visible in the south area, but he cautions us against forming a damnatory opinion on the mere evidence of outcrops from his experience in the Umaria and Korar fields. He suggests a thick seam in the direction of Isunoura and Taktai under the Infra-trappean (Lametas). Again, the fossil evidence (from near Amuari) suggested a Karharbari

[1] *Jour. As. Soc. Bengal*, IX, p. 903, (1840).
[2] *Mem. Geol. Surv. Ind.*, XXI, Pt. 3, pp. 29-36, (reprint 1925).

horizon for the beds of shale and coal there seen, half a mile south of Mangthar on the right bank of the Johilla.

North area : coal prospects.

A summary of the information on this field is given by Mr. Sinor[1], largely taken from Mr. Hughes' memoir. In both accounts three borings are mentioned and the results given of the trial of the coal for locomotives from the Marjada outcrop. Unfortunately the analyses given by Mr. Hughes does not include the moisture contents which is known to be high both in the Johilla and Umaria coals; nor is it stated which seam was opened at Marjada, but it is presumed to be the upper 17-foot seam. However, these analyses are quoted for comparison :—

	Volatile matter.	Fixed carbon.	Ash.
	Per cent.	Per cent.	Per cent.
Marjada	32·31	54·58	13·11
Do.	35·60	52·77	11·63
Do.	36·64	55·93	7·43
Umaria	26·70	59·20	14·10
Do.	26·40	60·90	12·70
Do.	28·40	60·70	10·90

I give below a few analyses of the picked components—vitrain, fusain and durain—of specimens collected during my visits to the South Rewah fields. My selection from the Johilla field was from the seam in the Johilla river, at the mouth of the Ganjra *nala*.

South Rewah coal.

——	Vitrain.			Fusain.		Durain.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture . .	15·43	9·66	16·76	7·85	2·56	5·99	6·94
Volatile matter .	31·25	44·30	34·06	29·55	19·06	21·36	24·1[illegible]
Fixed carbon .	51·46	42·66	44·76	52·90	69·32	40·48	35·63
Ash . . .	1·86	3·38	4·42	9·70	9·06	32·17	33·24
Caking property .	Does not cake.	Cakes strongly.	Does not cake.	None	None	None	Sinters slightly.
Specific gravity .	1·351	1·334	1·424	1·405	1·508	1·680	1·643
	(Umaria)	(Burhar)	(Johilla)	(Umaria)	(Johilla)	(Umaria)	(Johilla)

[1] *Op. cit.*, pp. 32-40.

According to Mr. Hughes there are 20 feet of workable coal in the north area of the Johilla field, and he thought the coal would be found at a shallow depth along an outcrop from near Pali on the east to Khodargaon in the west—nearly five miles. From these data he estimated 100,000,000 tons of coal, but it is probably safer to estimate ten feet of coal over four square miles and allow 25 per cent. for losses, thus arriving at an available coal reserve of 30,000,000 tons within a depth of 500 feet.

Sohagpur Coalfield.

This is the main area of coal bearing rocks in South Rewahand was given its name, by Mr. Hughes. In the original report[1] the area was given as 1,600 square miles, but this included an extensive area of coal measures in Korea State, which Dr. L. L. Fermor called the Sanhat coalfield[2], with an area of 330 square miles. Dr. A. L. Coulson further separated from the original Sohagpur coalfield a tract which he named the Jhagrakhand coalfield, which includes Dr. Fermor's Jhagrakhand Coal Area.[3] Dr. Coulson's Jhagrakhand coalfield has an area of about 60·7 square miles.[4] It is thus seen that the Sohagpur coalfield, as recognised to-day, has an area of about 1,200 square miles.

Captain Franklin is credited with first recording in 1830 the occurrence of coal in this Sohagpur coalfield in near Karaibahara below the confluence of the Tipan and Son rivers. The field was surveyed by Mr. T. W. H. Hughes in 1879-80, and re-examined by Mr. G. F. Reader, along the line of the railway, in 1899-1900. The western end of the field is near Ghunghuti railway station (23° 20′ : 81° 13′), 64 miles from Kanai (23° 22′ : 82° 14′), the eastern margin about the Hasia *nala*. The most northerly exposure is on the borders of Changbakhar State, north of Jaintpur, about latitude 23° 34′. The southern margin of the field is about the junctions of the Kewai and Tipan rivers with the Son, about latitude 23° 5′. Across its widest part, from north to south, the Barakar rocks show for nearly 30 miles.

Along the north, west, and south-west, the coal measures (Barakars) are covered by newer strata, the so-called supra-Barakars,

[1] *Mem. Geol. Surv. Ind.*, XXI, Pt. 3, p. 36, (reprint 1925).
[2] *Op. cit.*, XLI, Pt. 2, p. 150, (1914).
[3] *Op. cit.*, p. 212.
[4] Geological Report on Central Coalfields Railway, p. 14, (1923).

which have not been clearly separated. They include beds with fossil plants which indicate a Raniganj stage, although the lithological character of the rocks suggest Upper Gondwana strata. An outlier of these supra-Barakars occurs at Mahora Hill (3,368 feet ; 23° 21′ : 81° 50′) which is capped by basalt, originally part of a sill. Along the south and east, the coal measures are seen to overlie the Talchirs, which in turn rest on Archæan rocks. Over a narrow width of about ten miles, near Khaira (23° 7′ : 81° 27′), the coal measures are discordantly covered by Infra-trappean (Lametas) and these overlaid by the basaltic flows of Deccan trap age. There is an inlier of Talchirs, due to an east and west (north throwing) fault south of Barnhani (23° 14′ : 81° 48′) ; and the field as a whole is characterised by the presence of great sills and dykes of dolerite, which, although irregular in themselves, trend roughly along on east to west belts.

Geology.

As a result of his explorations in 1879-80, Mr. Hughes was led to believe that this extensive area of coal measures, with few attractive exposures showing seams of good coal of workable thickness, was disappointing as regards profitable exploitation—this in spite of the fact that the beds were almost flat. Subsequent investigation by Mr. Reader, in 1899-1900, near Burhar and Amlei and particularly at Dhanpuri proved that the main seam in this tract varied from 15 feet 6 inches to five feet. Later development has disclosed the fact that this seam at Dhanpuri is as much as 27 feet thick in places. Two collieries had been opened—one near Burhar and the other at Dhanpuri,—at the time of my visit in February, 1926. The Burhar Colliery is working on behalf of the Rewah State and the Dhanpuri quarries were opened by Messrs. Villiers, Ltd., of Calcutta. It should be stated that Mr. Hughes indicated this area as likely to contain the best coal in this part of the Sohagpur coalfield. He had also noted the prevalence of sandstones in the Barakars of the Sohagpur coalfield. This fact may account for the general concealment of the coal seams, and may someday justify boring to prove whether this field is truly poor in coal reserves.

Coal seams.

Dr. Coulson who, traversed this field in 1922-23, gives the following summary of Mr. Hughes' record of coal outcrops :—

1. In the Bakan *nala*, between Karaibahara and Mariaras, 3 feet 3 inches seam of coal, with 27·36 per cent. ash.

2. Near junction of Katna *nala* and Son river, five-foot seam, underlain by two thin seams, which are traceable for ten miles, stradding the Son, and could be worked. The main seam outcrops, between Bargaon and Kelhairi, once in the Jamunia, thrice in the Son, frequently in the Bageha, and twice in the Nargara. This is the Hughes seam 'par excellence' and evidently the Dhanpuri seam (above). The coal is non-caking. Hughes' sample gave the following analysis:—moisture 5·8 per cent., volatile matter 29·5 per cent., fixed carbon 55·0 per cent., and ash 9·7 per cent. This agrees with an analysis of the coal from the quarry at Dhanpuri, given as: moisture 5·2 per cent., volatile matter 27·9 per cent., fixed carbon 55·6 per cent., and ash 11·3 per cent. These are from the 24-foot seam. Sinor[1] gives three analyses of selected pieces of coal from a quarry near Pakaria, 1½ miles north of Burhar railway station, from an eight-foot outcrop of coal with carbonaceous shale:—

	A	B	C
—	Bright.	Fairly bright.	Bright and dull.
	Per cent.	Per cent.	Per cent.
Moisture	1·12	1·25	1·30
Volatile matter	28·06	27·51	24·30
Fixed Carbon	58·96	53·34	42·88
Ash	11·86	17·90	31·52

An analysis on a moisture-free sample (moisture 10·71 per cent.) from Burhar Colliery, made by the Alipore Test House, Calcutta, gave:—

	Per cent.
Volatile matter	32·75
Fixed carbon	56·83
Ash	10·42
Calorific value	6,846 calories.

[1] *Op. cit.*, p. 46.

3. Semra, north-west of Pakaria, where a pit was sunk in 1921. Sinor gives the following from two samples (seam not worked then) :—

—	A	B
	Per cent.	Per cent.
Moisture	4·50	3·56
Volatile matter	19·82	17·64
Fixed carbon	60·44	61·67
Ash	15·24	17·13
Calories from 6,110 to 6,580.		

4. Sahipur (23° 21′ : 81° 41′), fair quality coal, four feet seen but probably six feet to seven, in Kasser *nala*.

5. Harri, Katna *nala*, near Rampur (23° 12′ : 81° 41′), six feet of inferior coal.

6. Birhuli (23° 16′ : 81° 35′) three-foot seam in Birhuli *nala*, but inferior coal.

7. Nandnah (23° 20′ : 81° 29′) in the Jamuniha *nala* near village, five-foot seam, 4-foot 6-inch seam, and 3-foot 6-inch (split) seam. Analyses (dry basis) show :—

—	Five-foot.	4½-foot.	3½-foot.
	Per cent.	Per cent.	Per cent.
Volatile matter	23·84	26·55	18·28
Fixed carbon	62·50	62·89	48·15
Ash	13·66	10·56	33·57

These analyses are given by Hughes, who was of the opinion that these seams crop out in the mouth of the Khairi and Kanuk *nalas* four miles to the north.

8. Udri (23° 24′ : 81° 19′) in the Murna river, six miles north of Sohagpur, a five-foot seam of inferior coal is seen.

9. Gurara seam in Son river about 23° 28′ : 81° 18′. Hughes found a five-foot seam, and two thin seams below, of which the analysis is moisture 2·7, volatile matter 9·5, fixed carbon 40·5, and ash 47·3 per cent.

Mr. Hughes' map[1] shows several coal outcrops in the upper course of the Kanuk river around Jaintpur and up to Chatai (23° 29′ : 81° 53′); and several outcrops are shown in the eastern and south-east of the Sohagpur field, in the valleys of the Kewai, Gohirari, and the Katna, south of Mahora Hill. The most promising seam appears to be that in the Kewai west of Belha-Pariari (23° 8′ : 82°), where an 8-foot 2-inch seam (1 foot 2 inches carbonaceous shale) occurs. The analysis on a moisture-free basis gave volatile matter 25·49 per cent., fixed carbon 63·54 per cent., and ash 10·97 per cent. (moisture 10·3 per cent.).

Quantity of coal.

It is of course quite impossible from the data at present available to estimate the coal reserves of this great area of 1,200 square miles. With the new line of railway (Chirmiri branch of the Central Coalfields Railway) from Anupper (23° 6′ : 81° 42′) to the Kurasia coalfield about Chirmiri, only the southern and eastern parts have rail communication. But even this area must contain good coal, judging by the results of the analysis of the Belha-Pariari coal. So far as is known, there appear to be no records of deep borings. Until such exploration is made it is not possible to say that because exposures are few, the prospects are poor.

Production of coal.

The coal near Burhar had long attracted attention but development was not carried out until the close of the War when there was a shortage and prices soared to an enviable degree for producers. The output from these Burhar and Dhanpuri quarries and mines is given below:—

Year.	Tons.	Year.	Tons.
1919	*nil*	1927	82,541
1920	*nil*	1928	117,423
1921	37,060	1929	92,508
1922	42,693	1930	93,088
1923	80,125	1931	143,607
1924	131,174	1932	166,195
1925	116,170	1933	80,378
1926	108,599		

[1] With *Memoirs*, XXI, Pt. 3.

CHAPTER 12.

COALFIELDS OF THE CENTRAL PROVINCES.

CHHATTISGARH COALFIELDS: NORTHERN OR FEUDATORY STATES AREA.

General.

In an earlier chapter of this memoir on the distribution of the coalfields, it was shown that coal-bearing Gondwana strata occur in three separate regions of the Central Provinces—in the north-east or Chhattisgarh division; in the Satpura uplands; and in the Wardha valley. Each of these areas will be treated in a separate chapter.

The separation of the coalfields of the Chhattisgarh division from those of the South Rewah tracts in the Son valley is entirely artificial, as the strata are continuous across the political boundaries. The Sohagpur coalfield, for example, has now been subdivided into three, in spite of the fact that the Barakar series extends from one to the others. This subdivision is, however, necessary for political reasons.

Attention has already been drawn to the fact that the coalfields of the Chhattisgarh division and those of South Rewah are merely outcrops of Barakars in a vast area of Gondwanas. The Upper Gondwana strata, which overlie the older coal measures (Barakars) and other Lower Gondwana formations, extend from the north-east corner of the Chhattisgarh division, south of the Son river in the Kanhar valley, about 23° 45′ : 83° 45′, in a great westerly crescent, to the Hingir-Rampur region north of the Mahanadi, about 21° 50′ : 83° 55′.

The geology of this region has not been worked out in detail, but it is known that the strata of the Gondwana system[1] lie discordantly on Archaean rocks and are composed of both Upper and Lower Gondwana sediments. The Talchirs, where seen, always appear from below the coal measures (Barakars), and these coal-bearing rocks are covered by beds equivalent to the Raniganj and

[1] *Mem. Geol. Surv. Ind.*, LVIII, p. 107, (1931).

Panchets of the Damodar valley. Further, these Lower Gondwanas are again overlain by strata whose fossil evidence shows them to be the equivalents of the Mahadevas of the Satpura region. Faulting is seen in almost every area studied. Intrusions of dolerite are most abundant in the northern part of the crescent, and it is clear that these intrusions are related to the basaltic lavas of Deccan trap age which cap many of the higher hills and plateaux of the tract under consideration. In the hiatus between the basaltic lava flows and the underlying Upper Gondwanas there is sometimes found thin beds of so-called Lametas (Infra-trappeans), which are evidently more closely associated in time with the Deccan trap series than with the Upper Gondwanas. In some cases the faulting is seen to be newer than the volcanic rocks, but there are instances where an older period of faulting must have taken place—probably contemporaneous with the deposition of the Gondwana sediments.

Tatapani-Ramkola Coalfield.

This tract of Gondwana rocks lies about 15 miles west of the Hutar coalfield on a direct continuation of the belt along which the eastern coalfields of the Damodar valley occur. The tract under consideration is situated between the Kanhar and Rer rivers, between 23° 30′ and 23° 55′ north latitude, in the north-east of Sirguja State. The coalfields recognised in northern Sirguja were surveyed in 1878-79 by Mr. C. L. Griesbach and named by him the Tatapani-Ramkola coalfields.[1] The area was again traversed in 1922-23 by Dr. A. L. Coulson[2], then accompanying the Central Coalfields Railway Survey.

They comprise two separate areas of Damuda rocks, with the Rajkhetra tract of Upper Gondwana in between. The eastern and northern area extends in a strip three miles wide for over 40 miles from the borders of Rewa State near Pipra Hill (2,004′; 23° 51′: 83° 1′) eastwards north of Rajkhetra to the Banki and Sendur *nalas*, and then sharply southward to be cut off by the Tatapani fault. It is named after the *ilaka* of Tatapani, although the western half of it lies in Lakhanpur. The other area of Damudas lies south of Rajkhetra and extends westwards for 25 miles from about the ruined temples of Juba (near Manpura, 23° 43′: 83° 23′) down the Morne

[1] *Mem. Geol. Surv. Ind.*, XV, Pt. 2, (1880).
[2] *See* Geological Report, p. 53, (1923).

and up the Andherua valleys and across the trappean watershed of Gouri, finally to Ramkola village (23° 38′ : 82° 59′). It is named after the *ilaka* of Ramkola.

Among the basement, Archaean rocks, Mr. Griesbach recognised a Gneissic series and a Sub-metamorphic series of rocks which he thought might be the equivalent of the Lower Vindhyans. His description suggests that they may be the equivalents of the Dharwars. The Gondwanas were found to comprise Talchirs, Barakars, Raniganj, Panchets and Mahadevas; and it was noted that intrusions of dolerite of Deccan trap age traversed the Gondwanas, while lavas of the same age occurred on the gneissic hills to the south, and these outliers were capped with primary laterite. Perhaps the most notable feature in this area is the severe faulting to which the Gondwanas have been subject; this is further accentuated by the presence of several hot springs.[1] It is to one of these that Tatapani owes its name.

Geology.

Coal seams are found in the Barakar series. The area occupied by these rocks has been computed at about 100 square miles.[2] The whole area is stated to comprise 800 square miles, of which less than one-third include strata of Lower Gondwana age. The tract is best-treated in two parts—an eastern or Tatapani area, bordering the Kanhar river, and a western or Ramkola area, bordering the Rer river. A fair number of coal seams are known, but few are of good quality or of workable thickness.

Prospects for coal.

The best exposures in the eastern section are those in the Sendur river and its tributaries—the Banki *nala* and the Tatapani stream, and in the Iria *nala* and its affluents—the Ledho and Balsotha *nalas*. Dr. Coulson has noted a seam over three feet thick in the Tatapani *nala*, two miles north-west of Bhormi, which gave on analysis 5·16 per cent. moisture, 27·70 per cent. volatile matter, 43·30 per cent. fixed carbon and 23·84 per cent. ash. It does not cake and has a theoretical calorific value of 5,617 calories. In the Sendur river three miles north-west of Khijuria tola, he found a 6-foot 2-inch seam (11-inch parting of shale in middle) of coal rather steeply inclined (22°). A sample from the middle of the lower portion (3 feet 7 inches) gave—11·55 per cent. moisture, 25·25 per cent. volatile matter, 49·95 per cent.

Tatapani coalfield.

[1] *Mem. Geol. Surv. Ind.*, XV, Pt. 1, p. 22, (1878).
[2] *Op. cit.*, XLI, p. 80, (reprint 1922).

fixed carbon, and 13·25 per cent. ash. The theoretical calorific value indicated 6,235 calories as against 5,324 calories, determined in a bomb calorimeter. In the Banki *nala*, a quarter of a mile downstream from Gidhi, about eight feet of coal is exposed, but the sample obtained yielded 7·65 per cent. moisture, 23·55 per cent. volatile matter, 32·21 per cent. fixed carbon and 36·59 per cent. ash. The theoretical calorific value indicated 4,254 calories. This as fuel is of course worthless. Other exposures in the Banki *nala* and its vicinity—near Meguli, Chaki, Lawa and Karamdiha—and in the Balsotha *nala*, appeared to be thin seams of inferior coal.

Ramkola coalfield.

In the Suknai *nala*, near Sarsera, there are several exposures of thin seams of coal, the most important being, a 3-foot 6-inch seam north-east and a 2-foot 6-inch seam south-east of the village. The lower part of the latter seam gave, on analysis, 13·83 per cent. moisture, 28·04 per cent. volatile matter, 47·59 per cent. fixed carbon and 10·54 per cent. ash; the theoretical calorific value indicated 6,098 calories. Up the Budatand *nala*, a quarter of a mile from its junction with the Morne river, Dr. Coulson records a section with two seams of coal, 2 feet 6 inches and three feet, which represent the 17-foot seam of coal with shales recorded here by Mr. Griesbach. Above Manpur in the Morne river the seams, as now seen, are much thinner than those mentioned by Mr. Griesbach, and none appear to have been worth sampling. Without actual boring, which seems unjustifiable from the data available, it is not possible to pronounce a definite opinion on the prospects for coal.

The unattractive thicknesses of the seams, the poorness of the coal by analysis, and the isolated position of the fields, especially the Ramkola section, render it of little economic importance at the present time. At some future date, when more information is available and the country has become more accessible, its true value may possibly be ascertained by borings.

Jhilmili Coalfield.

This coalfield, recognised by Dr. V. Ball about 1872 and from whose unpublished notes it was described by Mr. T. W. H. Hughes, is named after the large village Jhilmili on the Rer (Rehar) in 23° 24′: 82° 51′. It was considered separately by Mr. Hughes[1] although

[1] *Mem. Geol. Surv. Ind.*, XXI, p. 62, (reprint 1925).

a portion of it lies across the Sirguja border in Korea State. Dr. L. L. Fermor[1], with his recognition of a Sanhat coalfield, as that part of the Sohagpur field in Korea State has presumably included in it that part of Dr. Ball's original Jhilmili field which lies in Korea State. It is thus necessary to remember that the Jhilmili coalfield as now accepted is only that area of Barakars in the Jhilmili *ilaka*, but the coal measures are nevertheless continuous with those of the Sanhat field, just as this field is really part of the original Sohagpur coalfield of Mr. Hughes. Now included also in the Jhilmili coalfield is that strip of Barakar rocks, which extends eastward across the Rer river, up the valley of the Mahan *nala*.

Geology.

The geology of the Jhilmili field is simple: there are no younger sedimentary beds than the Barakars, and these overlie the Talchirs, which in turn are discordantly superposed on the Archaean rocks of northern Sirguja (gneisses and Dharwars ?). There are two main faults across the field—(1) the E.-W. boundary fault along the north, bringing the Upper Gondwanas (undifferentiated supra-Barakars) to the north, and (2) the W. S. W. fault north of Jhilmili which throws south. Thus there is the structural aspect of a *horst* for the northern part of the field, west of the Rer (Rehar) river, east of this river Barakars are seen in the valley of the Mahan *nala* and its tributary the Kolua (Kohia), as far as Jajawal (23° 32′ : 83° 2′) and Anjni, two miles further east. Trending W. S. W. across the Jhilmili field, from north of Anjni and the Mahan valley, and through the central portion of the *horst* area west of the Rer river into Korea, there is a belt of igneous intrusions. These dolerite sills and dykes have an irregular distribution and are accepted as of Deccan trap age. It is difficult to ascertain if the faults are younger than the intrusions; but from the fact that intrusions occur along the line of the northern boundary fault (south of Kharra, Khudar, and, more extensively, Khanai Hill), it is probable that the faulting is older or of nearly the same age.

Coal seams.

For convenience of treatment the coalfield may be divided into four sections:—(1) the south area immediately west of Jhilmili to the Korea border, and south of the Barhi-Khajura fault; (2) the central area north of the Barhi-Khajura fault and the belt of igneous rocks; (3) the north

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 150, (1914).

area between the igneous belt and the north boundary fault; and (4) the Mahan area in the north-east.

In the south area, in sections seen in the Manikmara *nala* and its tributaries, Dr. Coulson[1] recognised four coal horizons:—

(top) *Horizon* IV, with thin seams.
Horizon III, small seams and two more than 6 feet.
Horizon II, a seam more than 3 feet 6 inches.
Horizon I, a seam more than 5 feet 4 inches.

The coal from this seam in the basal horizon (I) is evidently of excellent quality in the vicinity of Khadapara. Dr. Ball had noted two six-foot seams in the Manikmara bearing, north and north-east from Kaltanghat peak. Dr. Coulson thought borings might be put down west and south-west of Khadapara village, when such exploration is considered suitable.

In the central area a 4-foot 7-inch seam was met in the Rangama Jheria, a tributary of the Kirri, E. N. E. of Kundhour, near Kupi (23° 25′: 82° 41′). The analysis given by Dr. Coulson shows:—2·97 per cent. moisture, 26·02 per cent. volatile matter, 62·72 per cent. fixed carbon, 8·29 per cent. ash and an experimental calorific value of 7,092 calories; where the sample was obtained (three-quarter of a mile south-east of Kundhour), it is a non-caking coal. Dr. Coulson considered that this coal might be taken as underlying one square mile with an average thickness of 3½ feet, and might, seeing its good quality, provide 3,850,000 tons of coal in the same area.

Mr. Hughes noted that the chief coal outcrops in the northern area were located about Jumri (23° 26′: 82° 40′), which is separated from the Kundhour area by a belt of dolerite. He also shows an outcrop of coal in the 'hair-pin' bend of the Goknai *nala*, two miles above Rundaha, in the north-west corner of this northern section. As regards the coal of the north-eastern tract, east of the Rer river in the Mahan *nala*, we have practically no information. This portion of the Jhilmili field really lies in Ramkola *ilaka*, and is of interest, in that the coal measures must be connected with those of the Ramkola field beneath the Upper Gondwana rocks.

From the facts at his disposal, Dr. Coulson considered that the southern and central sections of the Jhilmili coalfield about Khada-

[1] Central Coalfields Railway Survey, Geological Report, pp. 23-31, (1923).

para and Kundhour possessed potentialities as a coal area. He has shown that some of these coals have caking characteristics. The areas are rather difficult of access, although the present rail-head of the line, from Anuppur to the Kurasia coalfield, is now distant only 25 miles.

Sanhat Coalfield.

This field has been recognised by Dr. L. L. Fermor as that part of the original Sohagpur coalfield (of Hughes), which lies in Korea State; it occupies 330 square miles of country. The continuation of the coal measure rocks, eastward into Sirguja State, is the Jhilmili coalfield discussed above. The Sanhat field was originally surveyed by Mr. Hughes[1] and Hira Lal and was rapidly re-examined by Dr. Fermor[2], who has given a valuable summary of the seams and coal. It was revisited by Dr. A. L. Coulson[3], a few years after I traversed it in 1919. There is no reliable record of the first discovery of coal in this region, but clearly it was sometime before Dr. V. Ball crossed the Jhilmili field, about 1870-71.

Geology.

Very little can be added to the geology of this area beyond the information given by Mr. Hughes. The area involved includes only coal-bearing Damuda (Barakar) rocks, followed on the north by supra Barakars (including Upper Gondwanas). The Talchirs show up from beneath the coal measures along the south, and rest on granitoid and other gneissic rocks of Archaean age. The eastern and southern margin of the field is traversed by a belt of igneous intrusions (dolerites) of Deccan trap age. No evident lava flows have been met with, even as caps on the highest hills in the Upper Gondwana tract to the north.

Coal seams.

Dr. Fermor has recognised provisionally three coal horizons in the Sanhat field, and on these the following notes may be of interest:—*Horizon* 1. In a belt 16 miles long in the eastern area, there are four outcrops of from four feet to nine feet of coal—Murwa (Pharkapani *nala*), Rakeya (Parewa Ghag), Nagar (Dummar Nakha *nala*), and Harra (Tutina Jheria). Assuming an average thickness of five feet of coal, there

[1] *Mem. Geol. Surv. Ind.*, XXI, p. 57, (reprint 1925).
[2] *Op. cit.*, XLI, p. 190, (1914).
[3] Geological Report, Central Coalfields Railway Survey, p. 13, (1923).

are in this horizon upwards of 5,000,000 tons of coal per square mile. Analyses of samples from three localities show:—

—	Murma.	Rakeya.	Nagar.
	Per cent.	Per cent.	Per cent.
Moisture	8·20	6·06	3·18
Volatile matter	29·50	28·16	26·98
Fixed carbon	46·34	50·46	37·60
Ash	15·96	15·38	32·24

Horizon 2. The next seam above that of the Rakeya, or horizon 1, is better exposed in the central (Nagar) and western acreas of the field. In four localities—Nagar, Ghutra, Salba and Balbahara—this seam varies from 3½ feet to 9¾ feet in measured thickness. Dr. Fermor was of the opinion that an average thickness of five feet might be assumed in the Ghutra-Balbahara area, so that over 5,000,000 tons of coal per square mile may be estimated in this tract. Analyses of samples from this horizon (seam) from the localities mentioned are given:—

—	Nagar.	Ghutra.	Salba.	Balbahara.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	3·38	5·48	3·28	5·71	3·10
Volatile matter . . .	25·62	21·06	23·58	26·33	23·40
Fixed carbon . . .	47·86	41·78	50·16	43·38	36·8
Ash	23·14	31·68	22·98	24·58	36·6

Horizon 3. A 2¾-foot seam of coal is recorded from Charcha (Barpani), from this the highest coal horizon, but it appears to be worthless as a workable seam. The analysis given (4·00 per cent. moisture, 25·61 per cent. volatile matter, 48·15 per cent. fixed carbon and 22·24 per cent. ash) shows it is as bad in quality as that of the middle seam (horizon 2).

The western end of the field, from Ghutra to the Rewa State border, was examined by Babu Bankim Bihari Gupta, under Dr.

Fermor's orders. But the samples from various outcrops of thicknesses less than five feet of coal in this tract—Bahi (Papar Jhorka), Khurpidhar, Putadan and Kerabahara (Gilapani *nala*) showed the quality to be similar to the poor coal of horizon 2.

Dr. Coulson, in his report, has included an extract from a letter to Mr. S. P. Flowerdew from Mr. Vyas Rao of Messrs. Dalchand Bahadur Singh, in which it is stated that their prospecting operations, north of Patna near Kutkona (23° 22′ : 82° 41′) on the Sirguja (Jhilmili) border, had proved two seams of coal of 12 feet and eight feet thickness. The upper (eight-foot) seam was thought to be somewhat inferior, but the lower (12-foot) seam was considered as equal to the best Kurasia coal. No analyses of these coals were given.

It may be mentioned in passing that the map which accompanies Mr. Hughes' memoir shows several coal outcrops along the northern and middle positions of the Sanhat coalfield, which may at some future date receive closer attention than can be given them by a hurried geological survey to-day.

Jhagrakhand Coalfield.

This area has been recognised by Dr. L. L. Fermor as the Korea State portion of the south-eastern corner of the Sohagpur coalfield of Mr. Hughes. Dr. Fermor[1] named this tract the Jhagrakhand Coal Area. It has an area of about 22 square miles of coal measure rocks, in a narrow strip one to three miles wide, trending southward for nearly 11 miles. The Jhagrakhand (23° 11′ : 82° 12′) *nala* flows eastward into the Hasdo, as do also the Kulharia and Neori streams, in all of which coal has been found. The Jhagrakhand seam is five feet thick according to Mr. Harris' report of 1912, but was considered over six feet near Tanki village by Lala Hira Lal[2] (1878-79) whose analysis gave :—moisture 6·7 per cent., volatile matter 28·2 per cent., fixed carbon 59·6 per cent. and ash 5·5 per cent. The area was re-examined by Dr. Coulson in 1923 who wrote :—

'I propose to include that part of Rewa State drained by the Jhimar and Kulharia *Nalas* and their tributaries, and also a small part of the Bilaspur district

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 212, (1914).
[2] *Op. cit.*, XXI, pp. 55-56, (reprint 1925).

drained by the upper tributaries of the Neori *Nala*, with the Korea State portion under the general name of the Jhagrakhand coalfield. The total area as shown .... is about 60·7 square miles.'

This is not the place to discuss the relative merits of subdividing a continuous area of coal measures into separate coalfields by political boundaries rather than by the catchment areas of streams. So long as it is clear that the Jhagrakhand coalfield is the south-eastern corner of the Sohagpur coalfield, just as the Sanhat and Jhilmili fields are its eastward extension into Korea and Sirguja respectively, the limits of the area are matters of convenience, and, as such, naturally in favour of the political limit.

Geology.

As already stated, the area considered is continuous north and west, with the Barakars of the main Sohagpur coalfield. To the east and south the Talchirs show up from beneath the coal measures, so that the dips will be north-westward at low angles. No Supra-Barakars or recognisable Mahadevas occur in this Jhagrakhand area. There are, however, several important dolerite dykes which strike westwards across parts of it. The whole tract lies south of the Central Coalfields Railway, which connects Anuppur on the Bilaspur-Katni branch of the Bengal-Nagpur Railway with the Chirmiri area of the Kurasia coalfield, *via* Bijuri (23° 16′: 82° 8′) and Manendragarh.

Coal prospects.

Dr. Coulson has confirmed the existence of a seam, about four feet to over five feet thick, in the Kulharia *nala* near Bhalmuri, and again in two places considerable distances apart near Dumarkachar. An analysis of this coal from a sample obtained by breaking up blocks of coal gave :—moisture 7·70 per cent., volatile matter 28·16 per cent., fixed carbon 55·24 per cent., ash 8·90 per cent. and a calorific value (experimental) of 6,489 calories. The material examined was not of caking quality.

From the descriptions it is not clear if the Bhalmuri-Dumarkachar seam is the same as the seam whose outcrop appears to extend southward from Jhagrakhand to Tanki. It was tested by Hira Lal and an analysis has been given. Dr. Coulson mentions yet another four-foot seam, 1½ miles south-west of Khongapani, which had been examined by private enterprise. A large block of this coal from the top of the seam gave :—moisture 5·53, volatile matter 22·37, fixed carbon 49·84, ash 22·26 per cent. and a calorific value (experimental) of 5,673 calories; it is also non-caking. The same

seam is seen, in the Bhukbhuka *nala* under a waterfall 2½ miles south-west of Khongapani, with a thickness of four feet six inches to five feet. A little lower (20 feet), at another waterfall, a second seam seven feet six inches thick was found, an analysis of the lower part of which yielded :—moisture 7·20 per cent., volatile matter 31·06 per cent., fixed carbon 55·05 per cent., ash 6·69 per cent. and a calorific value (experimental) of 7,056 calories. The material utilised is non-caking in quality. This lower Bhukbhuka seam was also encountered at the former locality (1½ miles south-west of Khongapani) where 28 feet of sandstone separates it from the upper seam. Here, however, the lower seam gave an ash content of 16·4 per cent. It is exposed in a tributary of the Karna Jharia. In this stream a mile south-south-east of Khongapani a 5-foot 8-inch seam was found, and another, a 5-foot 3-inch seam, a mile south of Khongapani, in a tributary of the Karna Jharia.

From information supplied to him, Dr. Coulson[1] records other outcrops in the Kulharia *nala* and its tributaries, the Jhimar *nala* and its tributaries, and the Jhagrakhand *nala* and its tributaries. He concludes that there are three chief horizons :—

Horizon III.—Coal in the upper reaches of the Bhukbhuka *nala*.

Horizon II.—Coal 5 feet 9 inches (two seams), 4 feet 9 inches (two seams), 6 feet 10 inches (two seams) and 5 feet 3 inches (one seam).

Horizon I.—Coal 6 feet 2 inches (two seams), 6 feet 4 inches (one seam), 7 feet 6 inches (one seam), and seven feet (two seams).

Dr. Coulson states that the lowest, horizon I, is the most important. It has two main seams of four feet and six feet (average), separated by a parting of 13 to 28 feet of sandstone. The quality is excellent in each case. He estimates a minimum thickness of three feet and four feet, respectively, for four square miles. This gives totals of 12,000,000 tons and 16,000,000 tons of coal, or in all 28,000,000 tons (or with the good quality somewhat more) in this lowest (I) horizon. The middle or No. II horizon is also valuable with its 4-foot 9-inch to 6-foot 10-inch seam, which, with an average of three feet under two square miles, will give over 6,000,000 tons of relatively poor coal (from the only analysis, ash 22·26 per cent.). However, it is evident that this Jhagrakhand area is valuable. It could be connected to the Anupper-Bijuri line by a branch line not more than seven miles long.

[1] Geological Report, Central Coalfields Railway Survey, pp. 19-20, (1923).

Kurasia Coalfield.

Named by Mr. T. W. H. Hughes[1] in 1885, after the only village, Kurasia (23° 13′ : 82° 24′), on the coal measures of this area. It lies east of the Hasdo (Hesthu) river in Korea State and covers 48 square miles of hilly country. It was only partially examined by Mr. Hughes, but has been since more fully explored. First by Dr. L. L. Fermor[2] in considerable detail, and Mr. J. L. Harris had visited it two years earlier. Railway communication has been established with this field across southern Rewa from the Bilaspur-Katni branch of the Bengal Nagpur line at Anuppur nearly 50 miles away. Two collieries have now been opened in this field: one, a State Railway colliery for the Bombay, Baroda and Central India Railway, known as Kurasia colliery at Chirmiri, and the other, a privately owned colliery, also in the Chirmiri area, on behalf of Sir Maneckji Dadabhoy (of the Ballarpur collieries in the Wardha valley). Other interested parties are Messrs. Tatas of Bombay and Dalchand Bahadur Singh of Calcutta.

Geology.

The geology of this field is simple. The Barakars are completely isolated and almost entirely surrounded by the Talchirs on which they lie almost horizontally. To the north, however, about Chitajhor, there is a belt of dolerite and basalt which overlies both the Talchirs and Barakars. This igneous rock is of Deccan trap age, and there seems to be little doubt that in this region it is all of an intrusive character, evidently connected with the dykes and sills which traverse Korea and Rewah States. There are also two little outliers of supra-Barakar rocks on the high ground in the eastern part of the area. Dr. Fermor has also recognised an exposure of the burnt outcrop of a coal seam in the Chirmiri area. Such an occurrence is often a good indication of the presence of coal of attractive quality.

Coal seams.

Dr. Fermor treated the field in two sections. That to the east of the road southward from Kurasia to Dubchola he named the Kurasia area, while that to the west he termed the Chirmiri area. He recognised not less than six coal horizons in the east or Kurasia area. The lowest (1) shows only thin bands of coal, (2) has the eight-foot seam of Gorghela *nala*, (3) has the thick over 11-foot 6-inch seam of the Bijaura

[1] *Mem. Geol. Surv. Ind.*, XXI, p. 59, (reprint 1925).
[2] *Op. cit.*, XLI, pp. 150 and 195, (1914.)

Jharia, (4) with the 6-foot 8-inch seam of the Nag Jhula, (5) has the 3-foot 6-inch seam of the Ama Jharia, (6) and there are indications of coal in the Kundo Pani. The quality of the coal from the localities named in the respective horizons stated may be gauged from the analyses below :—

Analyses of coals from Kurasia area.

Horizon.	1	2	3	4	5
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture . . .	4·73	6·38	2·78	9·10	10·02
Volatile matter . .	29·25	27·84	27·78	30·12	31·06
Fixed carbon . . .	45·88	56·28	60·86	46·96	45·64
Ash	20·14	9·50	8·58	13·82	13·28

N.B.—*Horizon* 1. 23 inches of coal in seven seams.

Horizon 2. Top 4½ feet of eight-foot seam, lower 3½ feet has 12·58 per cent. ash.

Horizon 3. Top 4½ feet of upper seam, lower seam 4-foot 8-inch sample gives 20·72 per cent. ash.

Horizon 4. Five seams totalling 6 feet 8 inches.

Horizon 5. 3 feet 6 inches of coal, shale rejected.

The localities are stated above.

As regards the Chirmiri area of this field, Dr. Fermor considered the most important exposure as that at the waterfall, known as Karar Khoh, in the Kaoria *nala*, where 36 feet of coal in seven beds occurs in 48 feet of strata. He considered that this seam belongs to horizon 4 of the Kurasia area, and with this correlation he records horizons 3, 4 and 5 in the Chirmiri area, of which horizon 3 is more attractive in quality than 5 if Table 10, page 203, of Dr. Fermor's memoir is correct (see page 209).

Analyses of Chirmiri coals (after L.L. Fermor).

—	Horizon 3.									Horizon 5.		
	K. 40.	K. 1.	K. 24.	K. 20.	K. 19.	K. 18.	K. 17.	K. 16.	K. 15.	K. 23.	K. 21.	K. 22.
	Upper Dubpani. (No. 30) 4′ 6″ seam (9″ coal shale excluded).	*Dubpani* (No. 32) 2′ 8″ sampled.	*Gaemara N. trib.* (No. 36) 4′ coal, top seam.	*Diwan Jharia* (No. 40). Upper seam, 3-4′.	*Karanli Dhar* (No. 41). Top 1½′ of 3′ seam.	*Jam Nala* (No. 46). 10″ coal.	*Bija Nala* (No. 47). 8″ coal.	*Bhalubhil N.* (No. 48). 1′ 3″ coal.	*Am Nala* (No. 49). 3″ seam picked.	*Bare Mandil N.* (No. 52). 3′ 6″ coal.	*Mangarmuhar N.* (No. 55). 4′ coal—upper seam.	*Mangarmuhar N.* (No. 55). 1¾′-3′ from lower seam.
Moisture . .	7·86	14·42	7·12	8·60	10·24	9·70	10·16	7·66	9·42	7·48	6·42	8·44
Volatile matter .	30·52	31·48	31·74	30·80	29·70	33·84	32·04	25·84	30·58	26·34	29·14	29·18
Fixed carbon .	52·20	44·85	51·34	46·76	47·20	47·26	49·22	47·50	33·60	41·92	34·78	48·24
Ash . . .	9·42	9·25	9·80	13·84	12·86	9·20	8·58	19·00	26·40	24·26	29·66	14·01
Total .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Note.—None of the samples caked, but K. 24 sintered slightly.

Analyses of coal from Chirmiri Colliery are given on page 210.

Besides the Karar Khoh exposure, horizon 4 is represented by several other outcrops—in the Sare *nala*, Gaemara *nala* and tributary, tributary of the Kaoria below Hathbanda, the Barsi Pani and several more. There are two attractive exposures of horizon 5—that of the Sendri Ama *nala* with two seams of over 7 feet 8 inches of coal in 27 feet 6 inches of strata, the Bara Mandil *nala* with three seams of over 7 feet 9 inches of coal in 33 feet of strata, and Mangarmuhar *nala* with three seams having 9 feet 2 inches coal in 33 feet 7 inches of strata. From the analyses it is clear that the only horizon which must be seriously considered is 4. For this reason I quote (page 211) Dr. Fermor's constructed section of the Karar Khoh, together with the analyses he gives of the coal in this section (page 212).

The following analyses (No. 13960) of large steam coal were made on the 29th June, 1928, by the Chief Mining Engineer, Railway Board, Calcutta.

Analyses of Large Steam Coal, Sir Maneckjee Dadhabhoy's Chirmiri Colliery.

—	CHIRMIRI COLLIERY.	
	No. 2 Seam.	No. 3 Seam.
Calorific value by Mahler bomb	6,923	7,063
	Per cent.	Per cent.
Moisture	7·78	7·71
Volatile matter	34·45	35·80
Fixed carbon	54·70	54·65
Ash	10·80	19·55
Coke	Non-coking.	Partly coking.
Ash, colour, clinker, etc.	Buff.	Buff.

Mr. C. S. Whitworth, Chief Mining Engineer, Railway Board, has also sent me the following analyses of the three seams now being worked in the collieries in Korea State (26th August, 1933) :—

	No. 1 seam.	No. 2 seam.	No. 3 seam.
Calorific value (calories) . . .	6,976	6,965	6,982
	Per cent.	Per cent.	Per cent.
Moisture	6·37	6·06	6·53
Volatiles	31·35	27·70	29·00
Fixed Carbon	56·73	59·30	58·15
Ash	11·92	13·00	12·85

(Analyses by the Government Test House, Alipore, on moisture-free basis.)

Kaoria nala *section at Karar Khoh* (after L. L. Fermor).

Ft.	in.		
....		Coarse-grained sandstones . .	....
5	0	. Carbonaceous shale	....
32	0	. Bedded, fine-grained, argillaceous sandstone.	....
4	7	. Interlaminated sandstones and shales	....
1	6	. Carbonaceous shale	....
4	6	. *Seam 1* —Banded bright and dull coal	Sample K. 5.
0	11	. Carbonaceous shale	....
3	0	. Carbonaceous sandstone with black shale (the steep part of the waterfall begins here).	....
4	0	. *Seam 2.*—Similar coal to seam 1 .	Samples K. 6, K. 7.
0	5	. Black shale	....
0	6	. *Seam 2A.*—Bright coal . . .	....
1	4	. Coaly shale	....
4	0	. *Seam 3.*—Dull coal with thin bright layers.	Samples K. 2, K. 8.
1	1	. Black coaly shale	Sample K. 8.
0	8	. *Seam 3A*—Mostly bright coal—rather pyritic.	„ K. 9.
2	6	. Micaceous sandstone (the surface of the pool is 14″ below the top of this).	....
0	9	Black shale	....
12	0	. *Seam 4.*—Mostly silky or dull coal .	Samples K. 4, K. 10, K. 11, K. 12.
1	0	. Black shale	....
12	0	. *Seam 5.*—Similar to 4, except or basal 2 feet, which is brighter coal.	Samples K. 13, K. 14.
....		Fine-grained argillaceous sandstones passing down into typical coarse grained sandstones.	....
TOTAL . 91	9		

91′ 9″ containing 37′ 8″ coal.

Analyses of Coal Samples from Kaoria Nala (Karar Khoh) (after L. L. Fermor).

——	K. 5.	K. 6.	K. 7.	K. 8.	K. 9.	K. 10.	K. 11.	K. 12.	K. 13.	K. 14.
	Seam 1—four feet six inches.	*Seam 2*—Central two feet.	*Seam 2*—Top one foot. Basal one foot.	*Seam 3*—four feet eight inches excluding four inches shale.	*Seam 3A*—Nine and a half inches.	*Seam 4*—Top four feet.	*Seam 4*—Central three feet eight inches.	*Seam 4*—Basal four feet four inches.	*Seam 5*—Top ten feet.	*Seam 5*—Basal two feet.
Moisture	8·72	8·08	9·08	6·79	8·74	8·12	6·24	6·74	8·04	8·96
Volatile matter .	30·36	27·62	29·84	27·38	33·86	28·09	23·48	31·96	29·32	32·88
Fixed carbon .	49·80	52·86	51·94	49·20	49·94	48·08	54·20	52·00	·28	52·66
Ash . .	11·12	9·44	9·14	16·72	7·46	15·71	16·08	9·30	11·36	5·50
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Caking properties. Sample K. 9 is the only one that caked. K. 5, K. 6, K. 7, K. 8, K. 10, K. 12, sintered slightly. The others did not cake at all. The ash in every case was brown to reddish brown.

Giving due weight to the thickness of each seam the following average composition may be assigned to the 37 feet 8 inches of coal forming this section :—

—	Average.	Limits.
Moisture	7·7	6·2 to 9·1
Volatile matter	29·1	23·5 to 33·9
Fixed carbon	51·2	54·2 to 48·1
Ash	12·0	5·5 to 16·7
TOTAL	100·0	..

Production of coal. The production of coal from the Kurasia and Chirmiri collieries is given below :—

Year.	Tons.
1929	*nil*
1930	3,517
1931	31,351
1932	113,858
1933	264,257

Reserves of coal. Dr. Fermor[1] states :—

'In view of the excellent quality of the coal in the two portions of this field —Kurasia and Chirmiri—and the considerable quantities of such coal that in all likelihood exist, probably some 10 to 20 million tons in each area, with possibilities of considerably larger amounts, this field is well worth the expenditure of considerable sums on boring operations. The chief difficulties that will be encountered in this field are probably small faults, and rapid changes in the thickness of the seams.'

In conclusion it might be added that the Kurasia coalfield has not been surveyed in detail, and, as pointed out by Dr. Fermor, the north-west portions of the field might thus be found to contain

[1] *Op. cit.*, p. 208.

other workable areas of coal. He has mentioned several villages—Chirmiri, Kadrewa, Banjaridand, Bhukbhuki, Chitajhor, and Ponri—near which coal has been noted, but these exposures were not examined by him.

Koreagarh Coalfield.

This small outlier of Barakar coal-bearing rocks, which occupies about six square miles of Korea State, was named by Mr. Hughes from the hill, 2,985 feet, which forms its highest point. Koreagarh hill (23° 7′ : 82° 29′) is capped by supra-Barakar rocks although the main mass is composed of coal measures. Thin seams of coal occur in the slopes of the hill, and one of these was noted to be nearly 4½ feet thick. The field lies roughly two miles south-east of the nearest point of the Kurasia field. It was visited by Mr. Harris in 1912, but since Mr. Hughes' visit in 1880 has not been examined by the Geological Survey of India.

The Barakar outcrop is entirely isolated by the Talchirs on which they lie. There are two outliers of supra-Barakars (Mahadevas ?)—one on Koreagarh and the other at the southern end of the field near Duggi. A dyke of dolerite evidently crosses westward north of the Duggi outlier of supra-Barakars. The area is somewhat isolated, but Mr. Harris has recorded coal exposures in the Ganga Gauri Jharia, the Sendha Am Jharia, and the Bela Jharia. These show seams of from three to five feet of coal. Other exposures are given by Dr. Fermor (from reports by the manager of the Khargaon zemindari) as Mendabera *nala* and the Lanjhar *nala* near Koreagarh; the Chatapani *nala*, Malin Ghag, Kurlia Ghag, Bija Ghag and Damankund Ghag in the Duggi area.

Bisrampur Coalfield.

This large tract of coal-bearing Barakar rocks lies in the wide lowlands of central Sirguja between 23° 8′ and 23° 26′ north latitude and 83° 21′ and 82° 54′ east longitude. It covers about 400 square miles of open country. It was mapped by Dr. V. Ball in 1872 and named by him after the capital of Sirguja State. The name of the town is now called Ambikapur (23° 8′ : 83° 12′). The first mention of coal in this area is by Col. Ouseley[1] and later by Col. Dalton.[2]

[1] *Jour. As. Soc. Bengal*, XVII, p. 65, (1848).
[2] *Supra*, XXXIV, Pt. II, No. 1, (1865).

Dr. Ball[1] found several outcrops of coal in this field. All these outcrops were visited by Dr. A. L. Coulson[2] in 1922-23. The larger north-eastern area is drained by the Mahan river and the south-western corner is drained by the Pasang *nala*, a tributary of the Rer. If the present railway from Annupur to Manendragarh (for the Kurasia coalfield) is extended to Jhilmili, it would be a simple matter for a branch line to be laid to the Bisrampur coalfield, but the obvious outlet from this landlocked region is southward from Ambikapur down the Mand river to the main line of the Bengal-Nagpur Railway (Calcutta to Nagpur) at Kharsia station.

Geology.

The Barakar strata are very flat-lying and thus the same coal seam may be frequently exposed in stream sections. Also no outcrops may be encountered over quite extensive areas. Talchirs are seen along the western and southern boundaries, but to the north and east Archaean gneisses and Dharwar (?) slates and quartzites (as near Karnji; 23° 19′: 83° 21′). It is only on the south, about Pilka hill, 2,921 feet (23° 8′: 83° 5′) that younger rocks—? Mahadevas—are seen. Dr. Ball estimated the thicknesses of the strata as follows:—Talchirs about 200 feet, Barakars, roughly, 500 feet, and ? Mahadevas of Pilka Hill probably 1,000 feet.

Except along the main boundaries—the north particularly—faults are not evidently common in this field, but this may be disproved by further exploration. Trap dykes also appear to be present in a few places, such as in the Mahan east of Durti in the north. The only other dyke noted is that in the Rer river east of Pachira in the south-west corner. There is no trap capping to the Mahadevas of Pilka Hill, although the Main Pat (3,500 feet) further south has a summit of upwards of 400 feet of Deccan trap basaltic lavas capped by laterite.

Coal seams.

Dr. Coulson has given a summary of the coal seams seen by him and Dr. Ball in the Pasang *nala*, though he did not see those of Dr. Ball. Among the outcrops of the Mahan river are:—those near Rajansuhi (several exposures) of seams more than 2 feet 2 inches to six feet, but high in ash (22·9 per cent.); others near Bagara, one of which is 5 feet 7 inches and another 2 feet 3 inches also high in ash (24·87 per cent.);

[1] *Rec. Geol. Surv. Ind.*, VI, pp. 30-38, (1873).
[2] Central Coalfields Railway Survey, Geological Report, pp. 31-42, (1923).

and those of Kotea, which are similar in thickness and quality. More than 2 feet 5 inches of good coal is exposed in the Gagar *nala*, about one mile north-east of Barka Dharia (23° 19′ : 83° 16′). The analysis of this (water-logged) coal shows :—moisture 12·00 per cent., volatile matter 27·97 per cent., fixed carbon 52·71 per cent., ash 7·32 per cent., and a theoretical calorific value of 6,647 calories. A fair quality coal occurs in a 7-foot 3-inch seam in the Mahan river, 2¾ miles south-west of Markadand. The analysis gave :—moisture 11·42 per cent., volatile matter 28·40 per cent., fixed carbon 46·23 per cent., ash 13·95 per cent., and a theoretical calorific value of 5,958 calories. The thick seam (more than 5′ 5″) in the Tulsi *nala*, a mile north-east of Tulsi, gave :—moisture 7·27 per cent., volatile matter 29·52 per cent., fixed carbon 37·63 per cent., ash 25·58 per cent., and an experimental calorific value of 4,898 calories. Of the two seams in the south-west of the field, Dr. Ball's specimens from the Rer river near Pundih and that from the Pasang south of Kumda were from thin seams. The analyses, however, indicate excellent coals in each case. The Rer river sample gave volatile matter 38·2 per cent., fixed carbon 57·7 per cent., ash 4·1 per cent. (moisture 4·1 per cent. in undried coal). The other coal is similar.

It is impossible to estimate the quantity of coal until the seams have been carefully mapped and the area explored by borings.

Reserves of coal.

The exposures above the confluence of the Gagar with the Mahan, about Markadand and Barka Dharia, appear more attractive than those of the Tulsi, in the Galphula *nala* tract. The Pasang and Rer seams are thin and so not workable unless they should be proved by boring to be thicker. And as to the samples analysed it may be said in justice that the coal is certain to lose much of its moisture when exposed to the air. Further, it is probable that the moisture content will be found to be less in the deeper seams, if such are proved by boring. The field has so far received only the most cursory examination, and it is thus difficult to make any but the most general statement in regard to its value.

Bansar Coalfield.

This little area of ten square miles of Barakar rocks lies five miles east of Ambikapur. It was mapped in 1888-89 by Hira Lal and

named by him after the little village of Bansar (23° 6′ : 83° 17′), situated on the north-west of the coal measures. An outcrop of coal (more than one foot) was met with a mile north-west of Darridih, three miles south of Bansa. A strip of coal measures extends west through Chendra, as though to join the belt of Talchirs, south of Ambikapur, which connects to the west with the Arand (Rer) river field north of Lakhanpur. This area has not been officially visited since 1889. It is entirely within the limits of Sirguja State, on the way from Ambikapur to the Mand valley, and could be more closely examined if railway communication southward is ever established.

COALFIELDS IN SIRGUJA AND IN THE BILASPUR DISTRICT.

General.

The following coalfields of south-west Sirguja and north-east Bilaspur are treated in this section :—Lakhanpur, Rampur, Matin, Panchbhaini, Damhamunda, and Sendurgar, and outliers of Murmuri, Bachrajkuar, Tulbul, Lakandih, Bhandar, Jajgi, Dhitori Hill and Chibri.

These coalfields and outliers of Barakar rocks lie in the tract southward from the Pilka hills (23° 8′ : 83° 5′) to the western edge of the great laterite plateau of the Main Pat, and spread westward across the headwaters of the Rer (Arand) river to beyond the Hasdo. Dr. V. Ball in 1870-71 on his way down the Matringa pass into the Mand River coalfield traversed the eastern area. He mapped in the geological boundaries on his line of march, but was unable to demarcate the western limits of the two coalfields he recognised—the Lakhanpur coalfield south-west of the Pilka hills and east of the Rer (Arand) river, and the Rampur (Sirguja) field between the Main Pat and the Ramgar hills (22° 54′ : 82° 54′). Meanwhile, about 1881, reports of coal from further west had come through to Mr. T. W. Hughes. Between 1885 and 1888, the whole region was carefully examined by Lala Hira Lal, who found that the Rampur (Sirguja) field continued westwards from beyond the Hasdo river to Korbi near Sarma (22° 51′ : 82° 25′) in Matin. He further found several smaller coalfields along the north and west of this Matin field. These were the Panchbhaini (22° 55′ : 82° 50′), Damha-

munda (22° 56′ : 82° 29′) and Sendurgar (22° 49′ : 82° 22′) fields. He also noted several outliers of Barakar rocks without coal seams in the adjacent tracts, which he distinguished as the outliers of Murmuri (22° 54′ : 83° 6′), Bachrajkuar (22° 51′ : 83° 7′), one two miles east of Tulbul (23° 3′ : 82° 48′), Lakandih (22° 57′ : 82° 52′), one north-east of Bhandar (22° 56′: 82° 51′), Jajgi Hill (22° 53′: 82° 30′), Dhitori Hill (22° 37′: 82° 19′), and Chibri (? 22° 38′: 82° 43′).

This region lies roughly between 22° 35′ and 23° 8′ north latitude and 82° 22′ to 83° 8′ east longitude. The basement rocks are Archaean gneisses and in places (in the north) rocks of the Dharwar type—slates, quartzites. On these rest the Talchirs, which are in turn succeeded by, and sometimes overlapped by, the coal measures (Barakars). On the higher hills to the south and south-east the Barakars are overlaid by sandstones which have been regarded first as Mahadevas and later as Kamthi (Hingir) beds, but in the absence of fossil evidence it has not been possible to prove them Kamthis. These supra-Barakars are believed to be unconformable to the coal measures. The Barakars and supra-Barakars pass under the Deccan traps of the south-west corner of the Main Pat, with Lameta clays between them in places. The Basaltic lavas of the Main Pat are capped with primary laterite. Outliers of the Deccan trap, with laterite in places, also occur in the south at the head of Rer (Arand) river.

Geology.

There is no doubt that these Gondwanas of the tract under consideration indicate a connecting link between the coal measures of Rewa, Korea and Sirguja and those of Korba, the Mand river, and the Raigarh Hingir coalfields. In fact the Gondwanas of the Rampur (Sirguja) area continue into the Mand valley down the Matringa pass. There must, however, be a strong fault in this vicinity, as the coal measures of the Upper Rer river in Rampur are quite 1,000 feet higher than those in the Mand valley. The straight lines of some of the boundaries in the coalfields under consideration indicate that faulting is also present in the Lakhanpur, Matin, and other fields yet to be discussed. Furthermore, trap (dolerite) dykes of Deccan trap age are also present, but such dykes are not common. One case at the south-west corner of the Main Pat shows the dyke in genetic association with the Deccan trap lavas. The country is still isolated and difficult; half a century ago it was the home of herds of wild elephants.

Lakhanpur Coalfield.

This field is named after the important village of Lakhanpur (22° 59′ : 83° 3′), which is situated on gneisses, just off the Barakars, at the south-east corner of the coal measure area. It lies south-west of the Pilka hills, and has as its north boundary an east-west fault which runs along the south slope of Pilka Hill. There is also, along its south-eastern margin, a fault that trends west-south-west from near Puputra (23° 2′ : 83° 4′). The field is divided into two, an eastern (Lakhanpur) section and a western (Laingha) portion, by the river Rer (Arand) which flows north through it. The eastern area was examined and named by Dr. Ball in 1870-71. It was estimated as covering 50 square miles[1], but this must now be accepted as an approximation for the eastern area. The western section was examined in 1887-88 by Lala Hira Lal[2] who estimated its area as 85 square miles, thus the whole extent of the Lakhanpur field is computed at 135 square miles. The name Laingha after a village on the watershed between the Rer and the Jhink is now suggested for the first time, purely for convenience of description.

Eastern and Lakhanpur section.

A fine dolerite dyke crosses this area on a east 15° north strike, just south of Katkona (23° 4′ : 83° 2′), where it is seen in the Chandnai *nala* cutting the finest seam of coal in this part of the field. This seam is of 5 feet 6 inches of coal (' equal parts of good, fair and burnable shaly coal '), but no analysis is given. Dr. Ball also noted coal outcrops in the Goinghata *nala*—a three-foot seam north-west of Parsori, and another 2-foot 4-inch seam north of Ambera. He also mentions a coaly shale in the Khekra *nala* E. S. E. of Ambera. No seams were evidently visible in the stream section of the Rer river.

Western or Laingha section.

This area extends over the watershed between the Rer and the Hasdo drainage and, as stated, occupies 85 square miles. The chief stream is the Rer river. Lala Hira Lal has noted several outcrops of fair to good coal, some of workable thickness. There is a 3-foot 6-inch seam west of Potka. He found over 7 feet 6 inches of coal on the right bank of the Rer, a short distance above the confluence of the Mani *nala*. Some of this is good, but the whole gave :—moisture

[1] *Rec. Geol. Surv. Ind.*, XV, p. 108, (1882).
[2] MS. Report, 1887-88, page 20.

7·98, volatile matter 28·82, fixed carbon 42·70 and ash 20·50 per cent., of non-caking material. In the stream from Lachi (22° 8′ : 82° 52′), about E. S. E. from Salih, he found a 4-foot 7-inch seam, and a little higher up the Lachi stream, at a lower horizon, he noted a 5-foot 9-inch seam. Neither of these coals cake, but their analyses show :—

—	Upper seam (4 feet 7 inches).	Lower seam (5 feet 9 inches).
	Per cent.	Per cent.
Moisture	7·92	9·84
Volatile matter	28·76	28·66
Fixed carbon	50·32	49·38
Ash	13·00	12·12

In a small watercourse, south of Salih, Hira Lal found a seam of 4 feet 8 inches of coal (soft coal one foot, stony coal 2 feet 4 inches, soft coal 1 foot 4 inches below), of which the analyses give an average, for the whole seam, of non-caking material :—moisture 8·06 per cent., volatile matter 26·89 per cent., fixed carbon 52·91 per cent., and ash 12·14 per cent. He gives other outcrops south of Laingha, but these are thin coals with carbonaceous shale. It is not possible to estimate the area underlaid by the Lachi (or Salih) seams, nevertheless this neighbourhood may prove suitable for exploration at some future date.

Mention has already been made of the several outliers of Barakar rocks in which no coal seams were met with, and it is unnecessary to refer to them again. Before dealing with the Rampur (Sirguja) coalfield and its westward extension into Uprora and Matin and Paharbula, it seems best to deal with the smaller fields between that and the Lakhanpur coalfield. These number three—Panchbhaini, Damhamunda and Sendurgar.

Panchbhaini Coalfield.

This field of about 4½ square miles of Barakars was named by Lala Hira Lal in 1885-86 from the range of hills, Panchbhaini (the five sisters; 22° 56′ : 82° 50′) in Paharbula *tappa* of Sirguja. The

Talchirs are exposed along the north boundary, while the south is defined by a fault. Coal was found in the Gerua *nala* S. S. W. of Pathri (22° 59′ : 82° 51′), and in the Jhapka *nala*, a mile south-east of Kotal (22° 58′ : 82° 47′). In both cases the seams are about three feet thick and evidently of good quality.

Damhamunda Coalfield.

This is another small area, 4½ square miles, of coal measures (Barakars) found and named by Lala Hira Lal in 1885-86. The village of Damhamunda (22° 56′ : 82° 29′) is on Talchirs at the north-east corner of the field. The Barakars occur close to the left bank of the Anjan stream, a tributary of the Hasdo. Thin seams of coal were found at three localities, in a half circle, within a mile west of Damhamunda, but analyses are not given and the field was not considered of economic importance.

Sendurgar Coalfield.

This important area of Barakars, roughly 20 square miles, was examined and named by Lala Hira Lal in 1885-86. Sendurgar (22° 49′ : 82° 22′) was then the only inhabited village in the area. It lies five miles west of the Hasdo river in Matin, in the Bilaspur district. Amlibahara (22° 55′ : 82° 18′) is situated within 1¼ miles of the north boundary of the field. The coal measures occupy the watershed, about eight miles long and 2½ miles wide, between the Bamni and Tenti *nalas*. The country generally is difficult of access except from the west, where a track connects with the Bengal Nagpur Railway at Pendra Road about 30 miles away. Several valuable coal outcrops have been found, and of these the more important are given below :—

In the *nala* about half a mile from the site of Bukbhuki (22° 51′ : 82° 18′), the section shows ten feet of non-caking coal having—moisture 6·50 per cent., volatile matter 20·20 per cent., fixed carbon 50·20 per cent., and ash 23·10 per cent. Two miles south of Amlibahara, in the Bar Jhar, a four-foot seam of caking coal occurs. This coal shows—moisture 8·46 per cent., volatile matter 30·74 per cent., fixed carbon 54·40 per cent., and ash 6·40 per cent. The same seam is (thought) to be represented by the outcrop in a tributary of the Bamni, north of the path from Pondi (? Ponri ; 22° 54′ : 82° 16′) to Bukbhuki.

A five-foot seam (with one foot shale) is present 1¼ miles south-west of Tanera (22° 51′ : 82° 23′), and another outcrops higher up under a waterfall. This upper seam on analysis gave—moisture 7·84 per cent., volatile matter 28·91 per cent., fixed carbon 54·90 per cent., and ash 8·35 per cent., and is non-caking coal. The same seam occurs in a *nala* one mile north-east of Sendurgar Hill, and in two other places in that vicinity. Hira Lal gave it as his opinion that this seam might vary from four to 12 feet in thickness, and that the whole area could be considered as underlaid by coal of some such thickness. If we allow a thickness of four feet of coal under ten square miles, the reserves are roughly 40,000,000 tons; but this estimate cannot be accepted without further exploration, which the quality of the coal would seem to justify.

CHAPTER 13.

COALFIELDS OF THE CENTRAL PROVINCES—*contd.*

CHHATTISGARH COALFIELDS :

SOUTHERN OR MAHANADI DRAINAGE AREA.

General.

Chhattisgarh coalfields.

This name is taken from the eastern division of the Central Provinces, between 19° 50′ and 23° 7′ north latitude and 80° 43′ and 83° 38′ east longitude, which comprises the plain forming the upper basin of the Mahanadi river. The name Chhattisgarh coalfields originally included the coalfields of Korba, the Mand valley and Rampur (Raigarh-Hingir of Dr. Ball). However, as the coalfield which spreads from the Rampur *tappa* of Sirguja in the Arand (Rer) valley to beyond the Hasdo river in the Bilaspur district is included in this area it is desired to change the name from Rampur (Sirguja) to Hasdo-Arand-(or Hasdo-) Rampur and include this —Hasdo-Rampur—coalfield in the Chhattisgarh fields. The name Hestho (Hasdo) was actually given to it by Lala Hira Lal in 1885-86, when engaged in the examination of the westward extension of the so-called Rampur (Sirguja) field.

Another modification has also been made in the recognition of four coalfields in place of the Rampur coalfield of Sambalpur. The names Raigarh, South Raigarh, Hingir (after a well-known zemindari in Gangpur State), and Rampur (Ib River) are thus brought forward. The last two fields lie in the province of Bihar and Orissa and have been dealt with in the chapter (IX) dealing with the Talcher coalfield. The other two, the Raigarh and South Raigarh coalfields, are best treated in this chapter, although it is to be admitted that the South Raigarh field extends into the Sambalpur district and joins the Rampur (Ib River) field at its south-western end at the Bagadia *nala* near Borkhol (21°′ 45′ : 83′ 44°′). With these emendations, it is hoped that future confusion in regard to these coalfields may be avoided.

It is of course fully understood that the Hingir and Rampur (Ib River) coalfields are merely the northern and eastern edges of

the large tract of Lower Gondwana rocks which extend continuously from the south of Sirguja, west of the Main Pat (plateau), through the Korba and Mand areas, to the Ib river in Sambalpur. At one time these strata were continuous with those of Korea and Rewa and the great area of Gondwanas on the Son valley. However, the two areas are now separated and the break in continuity occurs between the Lakhanpur or Rer river field of Sirguja and the Hasdo-Arand or Rampur (Sirguja) field. There are three small outliers of coal measures between these two important fields. These fields—the Panchbhaini, Damhamunda, and Sendurgar - have been included in those of the northern tract

Hasdo-Arand or Rampur (Sirguja) Coalfield.

The coal measures (Barakars), which occur at the headwaters of the Rer or Arand river, west of the Main Pat in Sirguja, were crossed by Dr. V. Ball in 1870-71 and named by him the Rampur coalfield. He stated :--

'The area for which the above name is proposed is bounded on the north by the Lakhanpur gneiss, on the east by the Mainpat, on the south it passes into the Mand area......, on the west it is connected with the great area of coal-measure rocks which stretches to Korba.'[1]

Dr. Ball was not able to give any estimate of the area involved in his Rampur coalfield, as his observations were restricted to the vicinity of the track from Lakhanpur to the Matringa pass. He, however, visited Ramgarh Hill, 3,202 feet (22° 54′ : 82° 54′), and records that the existence of coal in the slopes was known to Col. J. R. Ouseley[2] and Col. T. Dalton.[3] It is clear that Dr. Ball made a very brief examination of the Upper Rer or Arand valley, as he does not record a single seam of coal of any attractiveness, except the 4-foot 6-inch of 'stony coal' in Ramgarh Hill.

The area was partly examined in 1885-86, and more fully in 1887-88, by Lala Hira Lal. This geologist found, on the earlier occasion, that a large area of coal measures extending eastward from Sarma (22° 51′ : 82° 25′) near Korbi in Matin (Bilaspur district) for 36 miles to Garputa (22° 53′ : 82° 57′) near Painga in Rampur (Sirguja), and southward for about 15 miles from the

[1] *Rec. Geol. Surv. Ind.*, XV, p. 110, (1882).
[2] *Jour. As. Soc. Bengal*, XVII, p. 66, (1848).
[3] *Op. cit.*, XXXIV, Pt. II, No. 1, p. 24, (1865).

Chitai *nala* south of Mahora (22° 58′ : 82° 36′) in Paharbula (Sirguja) to Kendai (22° 44′ : 82° 37′) in Uprora (Bilaspur district) was really the westward continuation of the coal measures of the Rer (Arand) river which Dr. Ball had named the Rampur (Sirguja) coalfield. Hira Lal had called his area the Hestho (Hasdo) coalfield, but this has been altered erroneously in his MS. report[1] by someone else to the Lakhanpur coalfield.

There seems to be little doubt that this great area, of which only a fraction lies in Rampur, should be treated in at least four sections :—(1) The eastern or Rampur section in the Rer (Arand) valley; (2) a north-central area largely in the Atem river valley in Paharbula up to the Gej ; (3) a south-central section in the Chhoti Chornai valley, and in Uprora up to the Hasdo; and (4) a western section beyond the Gej and Hasdo rivers, the southern part of which lies in Matin. It is only the circumstance of priority which has permitted the name Rampur coalfield to stand. A more appropriate name is desirable, and there is another Rampur coalfield in the Sambalpur district at the Ib river. However, it is not easy to suggest another name. Ramgarh would be unsuitable for the same reason as Rampur, as there is another field of this name south of the Bokaro field in the Damodar valley. The Paharbula coalfield would perhaps be best, but it also is open to objection and so I have revived the name given by Hira Lal for its western section and refer to it as the Hasdo-Arand coalfield, but it is better called the Hasdo-Rampur field.

It is difficult to estimate the full extent of the Hasdo-Arand or Rampur (Sirguja) coalfield, but the coal measures must cover nearly 400 square miles in the *tappas* of Rampur and Paharbula in Sirguja State and in the adjoining zemindaris of Uprora and Matin in the Bilaspur district. The eastern (Rampur) and south-central (Uprora) sections are separated from the coalfields of the Mand river and Korba by younger (? supra-Barakar) rocks, but the coal measures must be continuous below these upper beds. There is also a tongue of Talchir rocks from the Tan into the Aharan valley, which shows that the Barakars of the western (Matin) area do not connect with those of the Korba field. The Sendurgar coalfield lies beyond the western (Matin) end of the field, and the outliers of Damhamunda and Panchbhaini lie between it and the Lakhanpur coalfield to the north.

[1] For 1885-86, p. 18, (1886).

The eastern (Rampur) section.

As already defined, this area is considered as occupying only the catchment of the Arand or upper Rer river. The Barakars in this section cover roughly 60 square miles as against 340 square miles exposed in the remainder of this great field. About 1¼ miles south-west of Bhakurma (22° 43′ : 82° 58′), in the Jantabahar tributary of the Borki (Barka) *nala*, there are three thin seams giving seven feet of coal in 10 feet 3 inches of section, but the coal shows 25 per cent. of ash. In another tributary in this vicinity, west-south-west of Bhakurma, there is a seam over 6 feet thick of non-caking coal, which gave—moisture 6·54 per cent., volatile matter 31·06 per cent., fixed carbon 38·84 per cent., and ash 23·56 per cent.

Under an imposing waterfall, a mile east of Kureli (? Kurel; 22° 44′ : 83° 5′), there is 3 feet 2 inches of coal with eight feet of carbonaceous shale and coal of poor quality. The analysis of the 3-foot 2-inch seam gave—moisture 7·80 per cent., volatile matter 30·40 per cent., fixed carbon 51·48 per cent., and ash 10·32 per cent. (of 'non-caking coal'). Under a cliff in the Bhalu *nadi*, south-east of Kedma (22° 45′ : 83° 4′), a three-foot seam is seen which yielded—moisture 8·72 per cent., volatile matter 28·24 per cent., fixed carbon 44·84 per cent., and ash 18·20 per cent., also a non-caking coal. Below a cliff of pebbly sandstone south of Garo (22° 45′ : 83° 7′) there is a section showing—(top) five feet coal, six inches shale, 3 feet 9 inches coal, five inches shale and seven feet coal (bottom). The strata dip south at 40°. The analyses are disappointing :—

——	Five-foot seam.	Seven-foot seam.
	Per cent.	Per cent.
Moisture	8·48	4·04
Volatile matter	26·72	27·06
Fixed carbon	38·40	30·70
Ash	26·40	38·20
Caking property	*Nil.*	*Nil.*

Thin seams (about three feet) are seen in several places—(1) in the Borki *nala* above the tributary from Sagar (Sagardih); (2) south-

east of Kesma (22° 45′ : 83° 4′); (3) a mile north-east of Dhora Kesora (22° 48′ : 83° 8′); (4) in the Rer river below junction with Khurkhuri *nala*; (5) in the Rer river two miles E. S. E. of Sair (22° 48′ : 83° 1′); (6) south-west of Lipingi (22° 51′ : 83° 3′); (7) in the Rer river south-east of Tunga (22° 53′ : 83° 1′) where coal debris was found; and (8) indications of coal east of Lachmanganj (22° 52′ : 83°).

The south-central (Uprora) section.

This lies south of Ramgarh Hill and west of the Kotora pass (Kotraghat) and includes that part of Rampur in the Chhoti Chornai drainage. In this tract three-quarters of a mile east of Bhakuhe (22° 44′ : 82° 54′), in the Bhangbahar tributary of the Dhamgora *nala*, there is a section showing—(top) five feet coal, six inches shale, four feet coal, four feet shale, six feet coal with sandstones below. The five-foot seam yielded—a non-caking coal with moisture 9·66 per cent., volatile matter 32·14 per cent., fixed carbon 54·54 per cent., and ash 3·66 per cent.

In the drainage area of the Chhoti Chornai, 2½ miles west of Sair, in two tributaries of the above *nala*, the following section is seen :—

	Feet.	Inches.
Thick bedded sandstones (top)—		
Coal (A)	6	0
Thick bedded sandstones	12	0
Blue shale	6	0
Coal	3	6
Carbonaceous shale	0	2
Coal (B)	6	0
Shale	1	0
Coal (C)	4	0

The analyses of seams A, B and C are given below :—

——	Six-foot (A).	Six-foot (B).	Four-foot (C).
	Per cent.	Per cent.	Per cent.
Moisture	7·54	7·98	7·24
Volatile matter	23·00	24·82	26·04
Fixed carbon	30·66	42·10	44·68
Ash	38·80	25·10	22·04
Caking property	*Nil.*	*Nil.*	*Nil.*

In the bend of the Chhoti Chornai *nala*, roughly 3½ miles west-north-west of Sair, a six-foot seam of coal is seen which thins out to the rise (dip 5°). The quality is good :—moisture 6·64 per cent., volatile matter 31·44 per cent., fixed carbon 44·16 per cent. and ash 17·56 per cent. (non-caking). Again about three miles north-west of Sair a 3-foot 6-inch seam outcrops, of which the analysis is —moisture 7·92 per cent., volatile matter 26·90 per cent., fixed carbon 46·16 per cent. and ash 19·02 per cent. (non-caking). A more convenient village from which to visit these localities would appear to be Koranja Sani (22° 47′ : 82° 58′), two miles north-east of Pindrakhi (22° 46′ : 82° 55′).

Further down the Chhoti Chornai, at the junction of the Sup (22° 48′ : 82° 55′), a four-foot seam is exposed in the left bank of the stream. The analysis of a sample gave—moisture 8·64 per cent., volatile matter 29·26 per cent., fixed carbon 49·20 per cent., and ash 12·90 per cent. (non-caking). About three miles west-north-west of Pindrakhi a section in the Chhoti Chornai shows gentle south dips with Carbonaceous shales.

	Feet.	Inches.
Coal	1	4
Carbonaceous shale	0	8
Coal	0	6
Carbonaceous shale	0	1
Coal	7	3
Coarse feldspathic sandstone	40	0
Coal	9	0
Shale	0	9
Coal	4	2
Carbonaceous shale	1	0
Coal	3	0

An analysis of the nine-foot seam below the massive sandstone was very disappointing moisture 7·28 per cent., volatile matter 24·22 per cent., fixed carbon 40·20 per cent. and ash 28·30 per cent. of non-caking coal.

A section in the Chhoti Chornai, at its junction with the Damet *nala* (? 22° 42′ : 82° 52′), shows four thin seams of coal, one of which is nearly 4 feet 6 inches ; a thick seam is suspected lower down stream. North of the deserted village of Purgia (Parogia), the present site is at 22° 47′ : 82° 51′, a 4-foot 9-inch seam was reported by Hira Lal, and another seam east of the existing village with an outcrop 330 feet wide on gently south dipping strata. In the Baigankharra *nala*, a short distance below the road between

Ghatbarra and Uchlanga and near Gidhmuri (22° 46′ : 82° 46′), thin coal seams are visible, but the exposure is not attractive.

Hira Lal refers to a section about four miles N. N. E. of Kendai (22° 44′ : 82° 37′), in the Bisrar *nala* showing 45 feet 6 inches of coal separated from a lower 5-foot 6-inch seam by nine feet of shale and overlaid by a massive sandstone. The entry is not very clear as only one analysis is given, showing—moisture 5·84 per cent., volatile matter 25·91 per cent., fixed carbon 47·90 per cent. and ash 20·35 per cent. (non-caking coal). Presumably it refers to the thick seam, but there is no remark pointing out the exceptional thickness. Further down the Bisrar *nala*, and 3½ miles north from Kendai, a seven-foot seam is exposed, of which the analysis shows—moisture 5·36 per cent., volatile matter 29·31 per cent., fixed carbon 42·60 per cent. and ash 22·73 per cent. of non-caking coal.

Where the track from Kendai crosses the Dhajag *nala* (22° 47′ 30″ : 82° 36′), a seam is exposed which is thought to be the same as that exposed in the Bisrar north of Kendai. The dips are gentle and rolling, but no analysis from this locality has been recorded. Again in the upper reaches of the Manasi *nala*, at the junction of two little streams, a mile W. S. W. of Kantalori (22° 52′ : 82° 43′) and half a mile north of the path from Kantalori to Jantasalka (22° 51′ : 82° 40′), a 3-foot 6-inch seam is exposed. And in the same *nala*, lower down, and about two miles north-west of Puta (22 49′ : 82° 43′), a four-foot seam is to be found.

The north-central (Paharbula) area.

This includes the Ramgarh hills. Two seams of coal, each less than 2 feet 6 inches, occur in an outcrop of six feet of coal and shales just under the massive sandstones overlying the coal measures. The Barakars are estimated at 800 feet on the slope of Ramgarh Hill (22° 54′ : 82° 54′). The two seams proved poor coal :—

——	Upper (2 feet 2 inches) seam.	Lower (2 feet 5 inches) seam.
	Per cent.	Per cent.
Moisture	6·78	8·12
Volatile matter	23·07	22·43
Fixed carbon	36·35	39·85
Ash	33·80	29·60
Caking property	*Nil.*	*Nil.*

Half a mile west of the hamlet of Chakeri (22° 51′ : 82° 54′), in a small stream, a 2-foot 4-inch seam of good coal outcrops. The analysis gave—moisture 8·80 per cent., volatile matter 26·30 per cent., fixed carbon 60·30 per cent., and ash 4·60 per cent. of non-caking material. Higher up in the Atem *nala* 1½ miles west of Garputa (22° 53′ : 82° 57′), near Ramnagar (Painga), another small seam is seen. In the Atem *nala*, a mile north of Parsa (22° 51′ : 82° 48′) a 5-foot 6-inch seam, base not exposed, outcrops. The analysis gave—moisture 7·50 per cent., volatile matter 28·70 per cent., fixed carbon 50·90 per cent., and ash 12·90 per cent. of non-caking coal.

South of the site of Kuhikundra, 1½ miles south-east of Khorbahar (22° 54′ : 82° 39′), in a small water-course, a four-foot seam outcrops, but contains iron pyrite. In another stream near by a 3-foot 6-inch seam—probably the same—occurs, and of this a sample yielded—moisture 10·30 per cent., volatile matter 28·60 per cent., fixed carbon 55·35 per cent., and ash 5·75 per cent. of non-caking coal. On the south side of Dongrikala Hill (22° 55′ : 82° 48′) in a *nala* tributary to the Ranai there is a section in which a seam 3 feet 8 inches occurs. A sample from this seam gave—moisture 8·98 per cent., volatile matter 27·07 per cent., fixed carbon 45·55 per cent. and ash 18·40 per cent., of non-caking coal. Other outcrops are reported in the Ranai *nala* a mile north-west of Khorbahar, and one 1¼ miles E. S. E. of this village; but both are less than four feet, though the latter including a shale band of six inches is of this thickness. The quality is good, showing—moisture 8·94 per cent., volatile matter 33·56 per cent., fixed carbon 52·65 per cent. and ash 4·85 per cent. (non-caking).

Thin coal seams occur two miles north-east and east of Bartunga village (22° 55′ : 82° 36′). The coal appears to be of good quality but too thin to be workable. A mile S. S. E. of Rundla (22° 52′ : 82° 35′) another thin coal outcrops barely 18 inches thick. In general it may be taken that the exposures seen in this north-central section indicate possibilities of further discovery when the area is more thoroughly explored.

The western (Matin) section.

The coal of Korbi near Sarma (22° 52′ : 82° 25′) was brought to the notice of Mr. T. W. H. Hughes early in 1881. A thin seam outcrops half a mile from Sarma on the track to Korbi to the east. Around the villages of Ponri (Pondi) and Rode (22° 50′ : 82° 27′)

there are several outcrops, evidently of different seams. One outcrop of a thin seam occurs a mile W. N. W. of Rode, which is thought to be the basal seam, seen also near Korbi, again west of Ponri, and also two miles south-west of Phulsera.

One mile south-west of Rode there occurs a second seam (middle seam) of 5 feet 2 inches including a two-inch band of shale. An analysis of this coal yielded—moisture 6·98 per cent., volatile matter 25·72 per cent., fixed carbon 57·05 per cent., and ash 10·25 per cent. (non-caking). A third seam of from 4 to 5 feet of coal also occurs in this section on a higher horizon. And in another exposure two miles south-west of Rode a section is seen with five feet of coal in three seams separated by partings of one foot and six inches. The top seam (two feet) of this section yielded a non-caking coal—moisture 7·94 per cent., volatile matter 23·61 per cent., fixed carbon 57·30 per cent., and ash 11·15 per cent. This seam is believed to be above those already referred to near Rode and is therefore the fourth or topmost seam.

Two miles south of Ponri (Pondi) and the same distance north-north-west of Chotia (22° 46′ : 82° 28′) there is a section showing 5 feet 6 inches of coal with four-inch parting of shale near the top. A similar seam, with a one-inch shale band in the middle, outcrops a mile from the west bank of the Hasdo river on the path to Parla (22° 46′ : 82° 30′). An analysis of this five-foot seam (near the Hasdo) shows a non-caking coal, having—moisture 6·92 per cent., volatile matter 26·78 per cent., fixed carbon 44·05 per cent. and ash 22·25 per cent. And half a mile north-west of Chotia, north of the track from Chotia to Banca, in a cavern, there is a 5-foot 8-inch seam with a middle band of two inches of shale. Finally, thin coal seams occur two miles S. S. E. of Lad (22° 51′ : 82° 29′).

From what has been stated in the preceding paragraphs it is evident that this Rampur (Sirguja) or Hasdo-Arand coalfield is as large as that of Bisrampur and contains a larger number of coal outcrops. The Sendurgar coalfield lies just to the west of its western end near Sarma. Should prospecting operations prove later that good coal does exist in workable seams in the Hasdo-Arand field it will be an incentive to lay a line from Pendra Road

railway station to the Sendurgar field and continue it eastward into the Hasdo valley to tap this important area.

Korba Coalfield.

This area in the lower Hasdo valley was mentioned favourably by Dr. W. T. Blanford [1], but must have been known between 1838 and 1845, as it is mentioned in the Report of the Coal Committee for 1845, though not given in their earlier summary (1838). The name appears to have been adopted after Dr. Blanford's examination. The field was examined in 1886-87 by Lala Hira Lal under Dr. W. King's orders, when several borings [2] were put down. The extent of the field is not stated, although the coal-bearing strata (Barakars) must occupy quite 200 square miles—roughly, 60 square miles east of the Hasdo and the remainder west of this river. To the west the Barakars send a tongue up the Aharan valley northwestward to about 22° 30′ north latitude; and another tongue goes west into the Kurung basin as far as Batara (22° 23′ : 82° 14′), over 30 miles from Korba (22° 21′ : 82° 42′). To the east it passes under the supra-Barakars of the watershed between the Hasdo and the Mand rivers, but a thin strip joins the Barakars of the Mand river field by way of Kerva near Sendripali (22° 14′ : 82° 54′), 15 miles south-east of Korba. Its north-east corner lies about Bela (22° 26′ : 82° 47′), roughly ten miles north-east of Korba.

Location.

Korba is situated on a motorable road 24 miles from Champa railway station (22° 2′ : 82° 40′) on the main line of the Bengal Nagpur Railway from Calcutta to Nagpur. The town and old fort are situated on the left bank of the Hasdo, while the thick seam, reputed to be 70 feet, is seen in two outcrops on the opposite bank just below the town. The explorations by Dr. King and Hira Lal showed that the coal contained many bands of shaly material, and the average of their assays indicated 37·28 per cent. of ash in the samples tested. Further, none of the samples proved the existence of any seam of good quality in the Korba section. A promising seam of 5 feet was discovered by Hira Lal in the Aharan river between Sumedha and Ghordewa (22° 23′ : 82° 38′), samples from which

[1] *Rec. Geol. Surv. Ind.*, III, p. 54, (1870).

[2] *Op. cit.*, XIX, p. 223, (1886); XX, p. 198, (1887).

and from a boring, 72 feet deep and 429 feet northwards from the outcrop, gave the following results :—

—	Outcrop (5 feet 3 inches).	Boring (6 feet) depth 72 feet.
	Per cent.	Per cent.
Moisture	8·52	5·30
Volatile matter	30·03	28·08
Fixed carbon	54·65	53·21
Ash	6·80	13·41

Mr. R. R. Simpson [1] states that a 22-foot seam outcrops in the Ganjar *nala*, 22 miles west of Korba. An outcrop of coal is shown on Hira Lal's field map (dated 1884) at the junction of the Ganjar and Dongara *nalas* (22° 20′ : 82° 21′), 1½ miles south-west of Kartela and about the same distance south-east of Daminia, but no details are given as to quality and dip. Another outcrop is shown in the Ghoghri *nala* (tributary to the Kholar *nala*) a mile north-west of Bagdewa (22° 27′ : 82° 31′), and a third (2′ 9″) coal outcrop in the Kholar *nala* above where the Baispur tributary joins it a mile north-east of Rail (22° 26′ : 82° 30′ 30″).

During recent years the Korba Coalfield has received attention from Mr. P. C. Dutt, the late Captain W. J. Considine and Messrs. Dunlop Bros. & Co., 12, Fenchurch Avenue, London. The personal efforts of Mr. John K. Dunlop have shown that the Korba or Jatraj thick seam is probably the same as the 150-foot seam exposed eight miles to the west of Jatraj (on the west bank of the Hasdo south of Korba), at Kusmunda (22° 20′ : 82° 36′), on the Lachhmi Inta *nala*. It seems possible that the Kusmunda seam represents both the Korba (Jatraj) and the Sonpuri (a mile south of Jatraj) outcrops of coal and carbonaceous shale. Thus the Kusmunda seam is believed to represent the combined Sonpuri seam and the Jatraj seam. The name Jatraj is here substituted for the Korba seam, which, as seen in the Hasdo river south of Korba, is really only the lower Kusmunda seam.

Exploration.

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 85, (reprint 1922).

The Sonpuri (or upper Kusmunda) seam shows:—

	Feet.	Inches.
Sandstone (roof)	39	0
Shale	6	0
C or top seam	16	6
B or middle seam	3	6
A or bottom seam	7	6
Shale	2	0
White sandstone (floor).		

Analyses of samples from these seams—A, B, and C—gave the following results:—

—	A (bottom seam).	B (middle seam).	C (top seam).
	Per cent.	Per cent.	Per cent.
Moisture	7·78	7·59	9·83
Volatile matter	26·87	25·71	28·39
Fixed carbon	36·63	36·26	44·44
Ash	28·72	30·44	17·34
Sulphur	0·62	0·50	0·48
B. T. U.'s	9,022	8,791	10,489

With regard to the details of the lower or Jatraj (Korba) seam as seen in the Jhenga *nala* near Jatraj, the thickness of the section of dull, bright, and shaly coal bands total 82 feet, but most of it is dull looking coal. Another section at Jatraj gave a total of 102 feet 8 inches of dull, bright, and shaly banded coal, and a careful study of the analyses of the various bands shows that the coal is poorer than the material from the upper seam near Sonpuri (above). The combined seams at Kusmunda appear similar, and it is almost certain that the seam as a whole will be worthless, but there are bands in it of good looking coal which might be examined.

Ghordewa.

Mr. Dunlop found a 20-foot seam of coal in the vicinity of Bhairotal, a mile south-east of Ghordewa, occupying a horizon between the Korba or Jatraj (lower Kusmunda) seam and the underlying five-foot Ghordewa seam. This has been called the Bhairotal seam, but no details are yet available regarding it. In this connexion it may be stated that

during my examination of the Korba area I came to the conclusion that the Kusmunda seam split up eastwards. The strata dip gently southward. East of the Hasdo river an eight-foot seam occurs in the Ramakhara (Ranpakhara) *nala*, 2½ miles south-east of Korbs, which yielded 21·54 per cent. ash and had a calorific value of 10,642 B. T. U.'s. This seam must be on a horizon near the top of the Sonpuri (upper Kusmunda) seam.

As regards the Ghordewa seam, it has been proved that this seam thickens to the east when traced through Dagania to the Hasdo about Charpara. An analysis of a five-foot core, from a depth of 238 feet, gave—moisture 5·37 per cent., volatile matter 20·19 per cent., fixed carbon 55·28 per cent., and ash 19·16 per cent. The calorific value recorded by Ivan Jones (analyst) was 10,803 B. T. U.'s. This analysis, compared with those given on an earlier page, indicates that the coal is not as good as at the outcrop near Ghordewa. However, a wagon sample sent to the G. I. P. Railway yielded the following analysis:—

Ghordewa coal from wagon No. 285037 at Byculla, Bombay.

	Per cent.
Moisture	5·90
Volatile matter	26·40
Fixed carbon	63·40
Ash	11·20
Calorific value	6,449 calories or 11,600 B. T. U.'s.

The report also states that 'It is quite up to mail standard'. This test was with 54 tons of coal specially mined and transported for trial purposes.

The boring operations carried out by Mr. Dunlop in the Ghordewa area proved the existence of two further seams below the Ghordewa five-foot seam, another five-foot seam and below that the Gamma seam. Neither of these seams have been tested, but it is known that they continue eastward as far as the Hasdo river. It is not absolutely certain if these seams are in anyway related to others found far east of the Hasdo river in the vicinity of Rajgamar (22° 23′ : 82° 51′).

The most important seam, quite six feet thick, met with east of the Hasdo, is seen in the Phulakdi *nala*, about a mile west of Rajgamar village. There is another outcrop, of gently inclined beds, with probably the

Rajgamar.

same seam, which occurs in the same *nala* south-west of the village. Until borings are put down at intervening places—Dumardih, Jhagara and Kharmora (22° 21′ : 82° 45′)—it is not possible to say if this Rajgamar seam is the eastern continuation of the Ghordewa seam. Analyses of samples from the outcrop a mile west of Rajgamar gave :—

—	Bottom 10 inches.	20 inches.	20 inches.	10 inches.	8 inches.	Top 14 inches.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Moisture .	7·73	8·27	9·35	9·12	8·89	Not analysed.
Volatile matter	34·55	30·35	31·21	30·79	29·06	..
Fixed carbon .	48·49	54·32	52·86	52·81	51·99	..
Ash . .	9·23	6·86	6·58	7·28	10·06	..
Sulphur . .	0·53	0·41	0·44	0·42	0·37	..
B. T. U.'s .	11,738	11,579	11,194	11,132	10,314	..

N.B.—The top 14 inches was weathered. Samples obtained from borings in this area gave equally good results, one of which shows the coal to have slight caking properties. It is likely this coal will possess definite caking properties deeper in the workings.

Several coal outcrops, in addition to those near Rajgamar, are now known east of the Hasdo river. Some are thin seams of no value, others show workable sections. Among the more attractive exposures may be mentioned those of the Ranpa-Khara *nala* east of Bhelài and also one north-east and another south of this village. All these are probably parts of the Kusmunda seam (upper or Sonpuri section). There is a large outcrop of shaly coal in the Kachendi *nala* east of Bisrampur (half a mile north of Bhelai). Another outcrop (probably only of a six-foot seam) occurs in the Kachendi *nala* north-east of Budeli village (22° 20′ : 82° 49′). These exposures belong to the tract south of Rajgamar.

In the northern area there are also a number of exposures of thin coal seams, but two of these appear more important than the others. Two miles east of Patrapali (22° 28′ : 82° 51′), up the

Supkon *nala* and near a hamlet called Ranaikhet, there is a ten-foot section showing :—

	Feet.
Weathered shales	3
Shaly *coal*	3
Coal	3
Hard shale	1 and shaly sandstone as a floor.

The other outcrop lies north by east from the village of Persakhola (22° 28′ : 82° 46′) and a mile up the Sarbahar nala. Here again the strata are gently inclined and the section seen has—(top) three feet coal, two feet shale and two feet of coal. The localities are somewhat inaccessible and no analyses have been made.

Coal prospects.

It is impossible to say anything definite regarding the coal resources of the Korba coalfield, owing to the uncertain data and without a detailed geological examination of the area. There is no doubt that the Ghordewa and Rajgamar seams are the most attractive, but there is every probability that workable sections of the Korba (Jatraj) and Sonpuri seams (and these combined as the Kusmunda seam) will be found. Some of the samples both from the Ghordewa seam and from the Rajgamar seam indicate material classifiable as coal of 'selected grade'. Without going into details it may be broadly stated that about 25 million tons of coal of good quality may be expected in the area west of the Hasdo river from the Ghordewa-Bhairotal, Jatraj-Sonpuri, and Kusmunda localities. Also, that a similar amount of good coal is to be expected east of the Hasdo river between Rajgamar and this stream, if the Rajgamar seam is proved to be the eastern representative of the Ghordewa seam. As regards reserves of coal of inferior grade, the quantity must be very large—upwards of 200 million tons from the several seams and exposures which have been mentioned.

The Korba coalfield is within easy reach of the main line of the Bengal-Nagpur Railway, barely 24 miles to the south across more or less open level country. Near the railway there is a wide outcrop of Vindhyan limestone of good quality and excellent for purposes of cement manufacture. The coal would be quite suitable, in pulverised form, for cement making. The coalfield appears very free of serious faults, and, so far as we know, no igneous intrusions have been found within the area occupied by the coal meas-

ures. However, in view of the existing depressed condition of the coal industry and the number of coalfields with railway facilities, it seems doubtful if the Korba area will receive close attention for some time. Dr. W. King[1] in his 'Progress of Geological work, Chhattisgarh Division' gives a geological map of 'the Chhattisgarh Basin' showing the Korba coalfield in its relations with the Mand river and Raigarh-Hingir coalfields, and another map in a later report.[2]

Mand River Coalfield.

It is not known when coal was first reported from the Mand valley. Dr. W. T. Blanford[3] partially examined the area in 1870. It was surveyed more fully, shortly after, by Dr. V. Ball.[4] A dozen years later the Mand River coalfield was explored by borings, carried out under the superintendence of Dr. W. King[5], who was assisted by Lala Hira Lal. The results were very disappointing due to the high ash content of the coals met with. Since then the field appears to have received no further attention.

The coal measures (Barakars) of the Mand valley belong to an extensive spread of Lower Gondwana rocks which are continuous from the Paharbula or Rampur (Sirguja) coalfield, between the Main Pat and the Hasdo river, south-eastward through Raigarh to the Rampur (Ib River) coalfield north of Sambalpur. The Korba coalfield is a western extension from the Mand area. A large part of these Lower Gondwanas consist of supra-Barakar rocks which are thought to be the equivalents of the Raniganj series. They are here known as the Hingir beds, and are petrologically similar to the Kamthis of the Nagpur area. The Barakars and underlying Talchirs show up from below these Hingir beds or supra-Barakars, and the Mand River coalfield is almost an inlier of the coal measures in the Mand valley. A narrow strip of Barakars, however, connects with the Korba coalfield to the west. The southern boundary of the field is evidently a fault trending south-east. The coal measures of the Mand valley are

[1] *Rec. Geol. Surv. Ind.*, XVIII, p. 169, (1885).
[2] *Op. cit.*, XIX, p. 234, (1886).
[3] *Op. cit.*, III, p. 71, (1870).
[4] *Op. cit.*, XV, p. 112, (1882).
[5] *Op. cit.*, XIX, p. 222, (1886); and XX, p. 194, (1887).

covered, to the west, north and east, by the Hingir beds or supra-Barakars (which may include Mahadevas in the higher hills).

The area occupied by the Barakars of the Mand valley must be roughly 200 square miles at least. It is nearly 38 miles from Amaldiha (22° 36′ : 83° 5′) at the foot of the Matringa pass, where the Barakars show up, to the junction of the Kurket and Mand rivers near Darjari (22° 4′ : 83° 8′). And the widest spread, over 16 miles, south of Rabkob (now Dharmjaygarh; 22° 28′ : 83° 14′, and situated on Talchir rocks) is between Potia (22° 24′ : 83° 16′) and Chachia (22° 21′ : 83° 1′). Dr. Ball had noted several coal outcrops, some attractively thick, in the northern part of the field—in the Gopal *nala* between its junction with the Mand and up to about east of Boro Hill, 1,895 feet (22° 32′ : 83° 7′). In this tract there appear to be four seams involved in a synclinal. They evidently reappear higher up stream above an inlier of Talchirs. The 3rd seam is of the order of 16 to 20 feet, but is interbanded with shale and little of the coal is referred to as good. Outcrops were also seen in other tributaries to the south—the Sarai, Kopa, Khanddhua, and in the Mand itself.

The boring operations, under the control of Dr. King, were, however, restricted to the neighbourhood of Tumidih (22° 6′ : 83° 6′) in the south. The seam is seen in the Mand river to the north-east of Tumidih. Thin seams had also been noted in the stream three-quarters of a mile E. N. E. of Nagoi, and an important section discovered by Hira Lal in the Pasang *nala*, three-quarters of a mile south-west of Tumidih. The borings proved two thick seams —one, that of the Mand exposure, of 19 feet, named the Jubilee seam, and the other, below it, 13 feet thick, named the Hira Lal seam. Samples taken foot by foot, of these two seams gave an average :—

——	Jubilee seam.	Hira Lal seam.
	Per cent.	Per cent.
Moisture	4·10	4·77
Volatile matter	24·46	25·53
Fixed carbon	26·49	34·20
Ash	44·95	35·50
Caking property	*Nil.*	*Nil.*

These assays were made at Tumidih camp by Hira Lal, and as the bore-hole samples were still more inferior, the investigation was closed. The exploration of the Korba area followed these disappointing results in the Mand River area.

Kankani Outlier.

Kankani (Kunkuni; 21° 59′ : 83° 9′) is situated at the north end of a small outlier of Talchirs and Barakars—each outcrop roughly covers one square mile—set among Vindhyan and Gneissic rocks. The exact place is south of the Bengal-Nagpur Railway and west of the Mand river. It is barely two miles south from Kharsia Station and about 12 miles W. N. W. from Raigarh. No coal seams appear to have been observed.

Raigarh-Hingir Coalfields.

There is some confusion about the name of the Barakar outcrops between the Mand Valley and the Ib River coalfields. The Mand River coalfield has been discussed above, and the Rampur or Ib River coalfield was discussed in an earlier chapter. The name Rampur is unfortunate as it has been used for the whole area east from the Mand field to the Ib river, and the name Rampur (Sirguja) has been used for another extensive area of coal measures between Sirguja State and the Bilaspur district. This question has already been dealt with by the suggestion that the field should be called the Arand-Hasdo coalfield and not the Rampur (Sirguja) field. In the case under consideration the name Ib River is given for the extreme east or Rampur end of the area of Lower Gondwanas extending south-east from the Mand area.

The name Raigarh coalfield expressly refers to the large area of Barakars exposed between the Kurket and Kelo *nalas* about 12 miles north of Raigarh (21° 54′ : 83° 24′). The name Hingir coalfield is revived for that strip of Barakars which extends into the northern end of the Ib River field near Ratakhand (21° 54′ : 83° 51′) from the Baisunder valley in the vicinity of Bhongrakachar (?22°1′ : 83°45′). And the name South Raigarh field is suggested for the corresponding strip of Barakars along the south-east boundary fault from the Kelo *nala*, five miles north of Raigarh, to the south-west end of the Ib River field at the Koilar (tributary

of Bagadia) *nala* near Borkhol (21° 45′ : 83° 44′). The intervening country is covered by supra-Barakars (Hingir beds), so far regarded as the equivalents of the Kamthis of Nagpur and the Raniganj series of the Damodar valley coalfields.

Raigarh Coalfield.

This area of coal measures lies in the north-east corner of Raigarh State and is drained by the Kurket and Kelo rivers. The extent of the Barakar outcrop is estimated at roughly 200 square miles. The limits of the field may be briefly stated as lying between the junction (22° 4′ : 83° 21′) of the Kelo and the Pazar (south-west of Kasdol) and Junadih (22° 15′ : 83° 31′) from south to north and Kurumkel (22° 16′ : 83° 16′) and Mendra (22° 6′ : 83° 35′) from west to east. It is not known when coal was first found in this area. The field was examined by Dr. V. Ball[1] in 1871 and again in 1875. The southern part of the area was seen by Dr. W. King[2], who did not consider it attractive enough to warrant exploration by boring.

Dr. Ball mentions several coal outcrops in the area, but most of them are thin seams associated with carbonaceous shales. In the Kurket or west section the top of a seam is exposed in the mouth of the Katang tributary. And higher up the Kurket, at the mouth of the *nala* from ? Gorgodi (22° 13′ : 83° 18′), which rises in Duldulla hill, a seam at least three feet thick is seen. Coal fragments are also found in the higher reaches of the Kurket.

In the Kelo and its tributaries Dr. Ball noted a six-foot seam in the Kelo, two miles above Khara (22° 12′ : 83° 31′) and two seams, six feet and four feet, lying almost level north-west of Pelma (22° 14′ : 83°31′). He had found an exposure with two seams of flaky coal, nearly five feet and six feet respectively with a six-inch parting, near the mouth of the Bendra, (22° 8′ : 83° 1′) east of Gari. Higher up the Bendra thin seams were seen near Janjhir (22° 7′ : 83° 33′). Finally, a short distance above the gorge of the Pazar south-west of Kasdol two thin seams are exposed, and another in the Digi *nala* near Deogar (22° 7′ : 83° 27′).

It cannot be said that this Raigarh field has been very carefully examined; no Talchir rocks appear to be present; the Barakars

[1] *Rec. Geol. Surv. Ind.*, IV, p. 105, (1871); and VIII, p. 110, (1875).
[2] *Op. cit.*, XIX, p. 221, (1886).

are almost entirely surrounded by the Hingir or supra-Barakars, except to the north where the coal measures rest directly on the basement gneisses. There are two little inliers of Barakars to the east, north and south of Ambo Hill, which almost connect it with the Barakars in the Jhajhai tributary of the Baisander *nala* forming the west end of the Hingir or Gangpur coalfield.

South Raigarh Coalfield.

This is a narrow strip of Barakar rocks which extends from the Kelo river near Laka (21° 58′ : 83° 23′) in Raigarh to the Bagadia nala near Borkhol (21° 45′ : 83° 44′) a distance of 28 miles in a south-east direction. The eastern half from near Berapali and the Bengal-Nagpur Railway Station of Jamga (21° 52′ 30″: 83° 34′) is in the Sambalpur district (with a little in the Hingir zemindari). The strip is barely a mile wide, so that the total area of Barakars is about 25 square miles. Both the northern and south boundaries are straight. To the north the Hingir beds follow the Barakars. A thin band of Talchirs separates the Barakars of the western part from the gneisses, which continue directly against the coal measures in the eastern part, evidently on a line of faulting.

The most interesting part of this small coalfield is that near Dibdorah on the Hingir *nala* (21° 48′ : 83° 40′). Two borings were put down in this area under the superintendence of Dr. W. King.[1] In the second bore, at a depth of 47 feet, a 14-foot seam was encountered, but the assay gave over 40 per cent. ash as an average for the seam. Very little of the seam appears to be of good quality. An attempt was also made to bore through the overlying Hingir beds near Birapali, but it was finally abandoned because the sandstones were found too hard for the drill then used.

The Rampur or Ib River coalfield has already been discussed in a previous chapter (10, page 170) of this memoir.

The Hingir or Gangpur coalfield has also been described on an earlier page (174) of this memoir.

[1] *Rec. Geol. Surv. Ind.*, XIX, p. 215, (1886).

CHAPTER 14.

COALFIELDS OF THE CENTRAL PROVINCES—*contd.*

SATPURA GONDWANA BASIN AND COALFIELDS.

SATPURA GONDWANA BASIN.

Nomenclature.

The name Satpura Gondwana basin is here used to include the tract of country south of the Narbada plains of Hoshangabad as recognised today. It includes the hilly region of southern Hoshangabad, northern Chhindwara, and north-east Betul. In it lie the Mahadeva hills around Pachmarhi (22° 28′ : 78° 26′), and, for this memoir, its limits may be taken as from Mohpani (22° 45′ : 78° 50′) on the north to Pathakhera (22° 6′ : 78° 10′) on the south, and from Sirgora (22° 12′ : 78° 53′) on the east to Sonada (22° 16′ : 77° 47′) on the west. It is known that the Gondwana strata extend east and west beyond the limits stated, but, as the beds involved outside these limits are chiefly Upper Gondwanas, as coal-bearing strata, their exclusion is not of serious consideration.

Geology.

Geological succession. The geological formations met with in the area under consideration are:—

The Recent and Older Alluvium and Laterite of the Narbada valley.

The Deccan basaltic lavas and dolerite dykes of Upper Cretaceous age.

The Infra-trappean or Lameta sediments a little older than the Deccan trap.

The Upper Gondwanas, subdivided as follows:—

Jabalpur beds (series) with the Chaugan stage.

Mahadeva series with the Bagra conglomerates and Denwa red clays and the Pachmarhi sandstones.

The Lower Gondwanas, subdivided into the—Bijori series (Upper Permian), Motur series (Middle Permian), Barakar series (Lower Permian), and the Talchir series below.

Bijawar limestones, banded hematites and shale (Purana).
Intrusive Granites of Chhindwara (Archæan).
Intrusive Dolerites (Lona Devi, also Archæan).
Dharwarian metamorphic rocks of Archæan age.
Gneisses and schists of Archæan age.

The pre-Cambrian (Purana and Archæan) rocks lie discordantly below the basal Gondwanas (Talchirs) and constitute the basement on which the Gondwanas rest. There is thus a great hiatus representing an immense period of time between the Gondwanas and the older rocks, and, possibly, a small hiatus between the Upper and Lower Gondwanas. A definite hiatus evidently occurs between the Upper Gondwanas and the overlying Lameta and Deccan trap rocks, and a larger interval of non-deposition between the topmost lavas and the Older and Recent Alluvium.

Faulting and intrusions.

Our geological work in the Satpura region shows that the Gondwanas lie in a synclinal trending E. N. E. to W. S. W. The Lower Gondwanas particularly appear to be restricted to this synclinal, which we think is of the nature of an old 'rift' valley demarcated both to the north and south by parallel faults. The Upper Gondwanas are suspected to have filled and spread beyond the synclinal. Nevertheless, it is clear that faulting has continued along the older lines, as both the Lower and the Upper Gondwanas have been subjected to faulting. With regard to the Deccan trap eruptions, it is certain that some of the faults are newer than the intrusions, but it is not evident that some intrusions have followed the lines of older faults.

The northern boundary.

Perhaps the most interesting structural feature of this Satpura Gondwana basin is the northern fringe which borders the Narbada plains. Broadly, there appear to be three lines of parallel faults trending E. N. E. to W. S. W. The newest of these faults is that in the Narbada plains along the base of the hills; it is a downthrow to the north. The oldest fault is a short distance to the south and within the hills. It appears to have been the northern limit of the Lower Gondwanas and has a downthrow to the south. Between it and the outer fault, along the 'horst-like' strip, the Archæan rocks often show as inliers along the boundary. The next fault is still further south passing south of Mohpani and was evidently largely contemporaneous with the

deposition of the Upper Gondwana rocks. Between this fault and the middle one, both having downthrows to the south, the Talchirs and Barakars appear in places, but the Upper Gondwana strata were deposited across both lines of older inner faults. These Upper Gondwanas and the Deccan trap lavas extend out under the alluvium of the Narbada and were, of course, dropped by the last or outermost fault.

Structure of basin.

The south boundary of the basin in the Chhindwara district is faulted. It is irregular in the Betul area, possibly due to the great erosion in the Tawa valley. The faults are not here clearly of different times of movement. It is possible movement has continued at different times on the same line. The latest displacements have involved the Deccan trap. The Lower Gondwana beds along the south dip northward, and, in the Upper Gondwanas, in the northern part of the basin, these northerly dips are continued. From this it would appear impossible for the Lower Gondwanas to reappear in the northern part, unless faulted. At a rough estimate, the Lower Gondwanas immediately south of the Pachmarhi plateau must be quite 8,000 feet thick (assuming a uniform dip of five to six degrees). It is a question whether the Upper Gondwanas thin rapidly to the dip and whether the strata above the Barakars are also wanting under the northern tract. At all events the search for coal in true Barakar rocks along the northern part of the basin has not so far thrown much light on these interesting problems.

Fossils in the Gondwanas.

Plant fossils have been found in certain strata in both the Lower and Upper Gondwanas. The Talchirs are generally unfossiliferous, but in the Betul area beds, regarded as Talchirs, contain plant fossils. The Barakars are, of course, characterised by coal seams, and poorly preserved plant remains, chiefly impressions of leaves or *Vertebraria*, are found almost everywhere. The Moturs, near their base, have been found to contain fossil wood (silicified) in the Pench valley and Upper Tawa areas. The Bijori series are also characterised by the presence of plant fossils of the Damuda flora, and it was in these beds, near Bijori (22° 22′ : 78° 30′), that the only animal remains, the Labyrinthodon, *Gondwanosaurus bijoriensis*, were found by Major Gowan in 1863.

As regards the Upper Gondwanas, no fossil (identifiable) has been found in the Pachmarhi beds. The Denwas and Bagras

have also proved unfossiliferous, except for the fragment of ***Mastodonsaurus indicus*** found in 1877 by Mr. T. W. H. Hughes near Jhirpa (22° 36′ : 78° 31′) in the Denwa river. The Jabalpur series have long supplied plant fossils and those recently collected by Mr. H. Crookshank indicate a lower geological position for some of the strata than was once believed. These beds have also provided large pieces of silicified fossil wood, and, in places contain thin seams of poor coal.

Detailed particulars of the occurrence of coal in the Upper Gondwanas will be given in the memoir dealing with the Mesozoic and Cainozoic coalfields of India. It will be enough here to state the localities in and around the Satpura region where coal has been met with in the Upper Gondwana (Jabalpur) strata. Eastwards these are as follows:—

Coal in the Upper Gondwanas.

1. Coal occurs in several exposures, in the Sihora tahsil, along the Mahanadi to the north-east of Jubblepore.
2. Coal found in jail well at 70 feet in station of Jubblepore itself.
3. Thin seam at Lameta Ghat on the Narbada nine miles W. S. W. of Jubblepore.
4. An exposure near Sehora on the Sher river.
5. Outcrop at junction of Sakkur and Hard rivers about 22° 45′ : 79° 5′.
6. Coal found south of Mohpani on the flanks of Nimbuagarh Hill.
7. Supposed Jabalpur coal in Denwa valley near Pursapani (22° 36′ : 78° 2′).
8. The coal in the Zumani *nala* below the Khatama caves (22° 30′ : 77° 44′).
9. The coal in the Moran river near Lokartalai (22° 22′ : 77° 26′).

It will be remembered that the coal of Umaria, in the Rewah country, was originally considered as of Upper Gondwana age until fossil evidence was obtained. However, except for the Pursapani occurrence above mentioned, we have satisfied ourselves that all the occurrences listed above are truly in Upper Gondwana rocks of the Jabalpur series. Coal has been obtained from 3, 4 and 5, but the seams are thin and the material poor; 7 will be discussed later in this chapter.

Coal seams and carbonaceous shales occur in the Bijori series of the Satpura region. These correspond to those of the Raniganj series of the Jharia and other coalfields of the Damodar valley. The line or belt of outcrop in which coal and coaly shales occur is from about four miles south-west of Delakhari (22° 25′ : 78° 37′), westward south of the Pachmarhi plateau, to the Sonbhadra a mile south-west of Bhatori (22° 23′ : 78° 12′), and on beyond the Tawa river to within two miles of Suktawa (22° 24′ : 77° 51′). The seams are thin and the coal of poor quality. So far as I am aware no serious attempt has been made to open any of the seams in this series.

Coal in the Bijori series.

The coal of Ranipura (22° 34′ : 77° 59′), a mile below the junction of the Tawa and Denwa rivers, is regarded by Mr. Crookshank as of Lower Gondwana (Damuda) age. This has not been proved. It may belong to the Bijori series and not to the real coal measures (Barakars). An attempt was made to work here (as well as at Pursapani barely five miles to the north-east) during the boom period after the War. The seam explored appears similar in each locality (three feet of coal), but no boring was carried deeper than 75 feet. Without further fossil evidence it is not possible to say if these exposures represent Bijori series in the former case and Jabalpur series in the latter. To me it seems they are the same beds and probably representatives of the Bijoris brought up by faulting.

A word of warning is necessary to avoid misunderstandings in regard to the red clays seen in the Pench Valley field. It has been stated that these beds—the Motur clays—are similar to the red clays of the Denwa series. The former belong to strata which conformably overlie the Barakar coal measures, the others are, of course, in the Upper Gondwanas. On a careful examination of the red clays of each of the formations named it is found that the Denwa clays were red when originally deposited. The red clays of the Pench valley beds (Moturs or Middle Damudas) on the other hand are found to pass down into buff to pale greenish calcareous clays. In fact in the deep glens of the upper Tawa, where erosion has been relatively rapid, there is an absence of red clays, and the unweathered buff to greenish clays are everywhere seen. The gradations from red to greenish buff clays can be studied in several exposures

The red clays.

in the Pench valley area itself. This change in colour is also accompanied by a liberation of nodular carbonate of lime (*kankar*). Some of the greenish buff Talchir clays also show a red colour, where an outcrop has been exposed to prolonged weathering.

Greenish buff clays.

The most typical greenish buff clays are the splintery needle shales of the Talchirs. They are in fact one of the type rocks of the Talchirs and their recognition is important to those searching for coal. As stated above, the clays of the Moturs in the Tawa valley are often very like the Talchir clays both in colour and character and can be at times mistaken for Talchirs. Again, the Denwa red clays, where traversed by big dolerite intrusions, are often seen to pass into greenish buff clays as the contact with the dyke is approached. This change is evidently the reverse in character of the weathering of the Pench valley Moturs. In places these altered Denwa clays so closely resemble the Talchir clays that they have actually been mistaken for them. However, their true nature can be readily recognised after a study of such exposures as are common in the vicinity of Jhirpa and further east in the Denwa valley.

Karharbari stage.

Dr. O. Feistmantel found that the plant fossils of the coal measures at Mohpani included *Gangamopteris cyclopteroides* and others, which inclined him to the view that the strata involved represented the Karharbari stage of the Giridih coalfield. On similar evidence he formed the same opinion of the Sonada area in Betul. We are not now insistant on this point, and regard the coal measures of the Satpura region as Barakars, and very likely basal Barakars. There is little doubt that the passage from the Talchirs up into the coal-bearing Barakars is a very gradual one in the Satpura coalfields.

Original spread of Damudas.

Having briefly indicated the peculiarities of the Gondwana strata in the Satpura region it is necessary to say a word in regard to the original limits of the coal measures of this great area. The extent of these rocks falls within the area outlined in an earlier paragraph—roughly, 70 miles from west to east and 30 miles from north to south. But the exposed coal measures (Barakars) along the south margin, and in one place (Mohpani) on the north, is but a fraction of the whole. We believe these Barakars do underlie all the younger strata above them, but by far the larger part of these concealed Barakars must be buried so deeply as to be beyond

the reach of exploitation. It is possible that at the time of their deposition they were continuous southward to the Wardha Valley tract. They have been removed by denudation from the intervening area, and it will thus be a waste of time to search for concealed coalfields either in Chhindwara or in Betul, south of the limits of the existing coalfields. It is true that Damuda strata (Kamthis, equivalent to the Raniganj series), are seen in the base of the hills north of Ellichpur and north-west of Nagpur, but no coal measures have been discovered below them. Of the two areas just mentioned that near Ellichpur has the potentiality of concealed coal measures should anyone desire to carry out an experimental boring to a great depth.

SATPURA COALFIELDS.

General.

In the accompanying description, I propose to discuss the exposed Barakar coal measures in the following areas:—(1) the Mohpani-Gotitoria field; (2) the Pursapani and Ranipur exposures; (3) the Sonada area of Betul; (4) the Shahpur fields of Katasur, Mardanpur and Gurgunda; (5) the Dulahra and Pathakhera and Upper Tawa fields; (6) the Kanhan fields of Kalichhapa, Damua, Datla, Jamai and Hingladevi; and (7) the Pench Valley coalfields from Barkui to Sirgora, including that of Gajandeo. The last is to-day the most important area, but the Kanhan and Shahpur areas may attract attention at a later date.

The occurrence of coal at Mohpani and in the Shahpur area of Betul was known about a century ago, and in Chhindwara about 1854. Coal from near Sonada was tested as early as 1848. And between 1860 and 1870 borings were made near Mohpani, and in the Dudhi and the Tawa valleys. The mines at Mohpani were opened in 1862 and, after some delay, railway communication was made available. The Pench Valley field was first given railway communication *via* Nainpur and Chhindwara through the Bengal-Nagpur Railway, about 1905, and the line from Chhindwara to Nagpur was opened in 1912. The G. I. P. Railway also opened their line to this field *via* Betul and Amla, about 1915. The colliery at Mohpani (Gotitoria) was closed down in 1929, and the connecting line from Gadarwara taken up.

Mohpani Coalfield.

The occurrence of coal in the Sitarewa river near Mohpani (22° 45′ : 78° 50′), evidently long known by the people, was discovered by Colonel J. R. Ouseley[1] as far back as 1835. He had 206 bullock loads of coal despatched for trial in the Bombay dockyards in 1838. The area was visited by Mr. J. G. Medlicott[2] during 1855-56, who considered it one of the most important coal areas then known in the Narbada territory. The Narbada Coal and Iron Co., Ltd., was formed in 1860 and a colliery opened at Mohpani in 1862 in anticipation of railway connexion with Gadarwara (22° 54′ : 78° 48′) station. There was delay in the laying of this line, which was not completed till 1870. The difficulties of the area were made known by the investigations of Mr. H. B. Medlicott [3], who examined the area on several occasions about that period. His intensive and extensive explorations included the area at the Sitarewa exposures and others : to the east at Patkuhi (22° 45′ 30″ : 78° 52′) ; to the west at Tundni [4] (22° 43′ : 78° 44′) ; in the Anjan gorge south of Fatehpur (22° 42′ : 78° 31′) ; and out in the Narbada plains at Sukhakheri (22° 48′ : 78° 48′) and elsewhere. In all these cases the geological inspection was supplemented by borings, but with disappointing results.

The explorations at Mohpani had meanwhile proved the existence of four seams of coal, roughly, as follows :—

——	1862.	1874.	1892.
	Feet.	Feet.	Feet.
No. 1 *Coal*	8	9½	14
Splint	..	2½	2
No. 2 *Coal*	12	16½	18
Splint	.	1½	..
No. 3 *Coal*	3	3	3
Stone	..	2	2
No. 4 *Coal*	6	6	6

[1] *Jour. As. Soc. Bengal*, IV, p. 648, (1835).
[2] *Mem. Geol. Surv. Ind.*, II, p. 169, (1860).
[3] *Rec. Geol. Surv. Ind.*, III, p. 63, (1870) ; IV, p. 66, (1871) ; V, p. 109, (1872) ; VIII, p. 63, (1875) ; and XII, p. 95, (1879).
[4] No. 3 bore-hole at Tundni proved coal the analysis of which showed 4·4 per cent. moisture, 32·4 per cent. volatile matter, 43·6 per cent. fixed carbon and 19·6 per cent. ash (*see* G. S. I. Laboratory Book, Vol. I, p. 287, dated 8th April, 1877).

The beds have dips up to 22 degrees. The coal was found to be of excellent quality, but the area involved was only 30 acres near the Sitarewa. In spite of numerous difficulties connected with faulting, water, and other mining worries (fires) and the expenditure of large sums of money, this state of things continued till 1892. Then Mr. F. L. G. Simpson, the manager, with the assistance of Dr. W. King and Mr. T. D. LaTouche, of the Geological Survey, discovered a workable area of the same seams near Gotitoria (22° 44′ 30″ : 78° 19′) about two miles west of Mohpani. This area was carefully proved and the workings at Mohpani finally closed down in 1902 and the new area developed.

In 1904 the collieries of the Narbada Coal and Iron Co., Ltd., were sold to the Great Indian Peninsula Railway Company. An area of nearly 100 acres was available at Gotitoria and, although the search by borings was not relaxed, a steady output from the new mines was maintained for 20 years. By 1925 it seemed doubtful if the output of coal from here, under difficult conditions, was worth while, in view of the better prospects in the Bokaro coalfield in the Damodar valley. The economics of the problem were fully threshed out, and, although there were differences of opinion on the matter, it was finally decided to close down all operations in the Mohpani-Gotitoria area. The last recorded output from these collieries was 71,482 tons in 1927, since when the collieries have been dismantled, and the ten miles of railway to Gadarwara have also been removed. Thus ends the history of this unfortunate field; but, before closing my remarks in connexion with it, I feel that some particulars in regard to the seams and the geology should be stated.

Geology.

The strata involved in the Mohpani-Gotitoria area, or the so-called Sitarewa coalfield, comprise the Narbada alluvium to the north, trap intrusions of Deccan trap age, the Jabalpur beds and the Bagras of the Upper Gondwanas to the south and east, and the coal-bearing Barakars (basal or Karharbari stage), and Talchirs of the Lower Gondwanas. The Bagra conglomerates underlie the sandstones of the Jabalpur series with apparent conformity in the slopes of the hills to the south, and must overlie the Barakars with a great time-break, if not actually unconformably. The Barakars appear to be conformable on the Talchirs. No older rocks are seen in this area, but Archaean siliceous limestones of the Bijawars are seen

west of Tundni. The area is faulted and has the general structure of an anticlinal with a pitching axis dipping eastward, as the Barakars can be followed round from south to north just east of the Sitarewa. A large mass of dolerite at Gotitoria Hill is thought to be a laccolite now exposed by denudation. The north limb of the anticlinal shows almost vertical dips in the Talchirs, Barakars and Upper Gondwanas, which include at least one dolerite dyke, following the strike of the beds. The south limb of the fold shows the Barakars and overlying Upper Gondwanas (Bagra conglomerates), dipping somewhat steeply to the south (under the hills). To the west, in the Gotitoria area, the north limb of the fold has not been proved. Mining has been restricted to the south where the dips are relatively gentle. The faulting is irregular and can be broadly regarded as breaking up the Barakars into blocks. The difficulty has been to locate the coal-bearing blocks within workable limits. Boring is rendered difficult through the Bagra conglomerates by loose pebbles.

Coal seams.

As already stated four seams of coal have been proved in the Mohpani-Gotitoria areas. At a rough guess the coal won from the Gotitoria mines during the 25 years of their existence may be placed at some 1,250,000 tons, since 1893, or, say, a million tons since the colliery was bought for £40,000 (in 1904). The total amount extracted from the old mines at Mohpani has been given as 450,845 tons (probably a little more) of coal. At the time of his valuation of the new Gotitoria area, Mr. F. L. G. Simpson estimated the reserves there at 7,169,362 tons of available coal and 837,094 tons of splint. In making these estimates, Mr. Simpson assumed an extraction of two-thirds of the coal in the four seams. The thicknesses of these seams were taken as: No. 1 seam, 11 feet with a six-foot bed of splint; No. 2 seam, 25 feet; No. 3 seam, five feet; and No. 4 seam, $6\frac{1}{2}$ feet. And these thicknesses have been verified during the mining operations at the Gotitoria workings and borings. For example, taking the sections of borings (Nos. 24 and 26), near the shafts at Gotitoria we have:—

(*a*) No. 24 boring has—

	Feet.	
No. 1 seam (top of) at . .	41	20 feet 8 inches of *coal* and splint.
No. 2 seam met with at . .	102	26 feet 6 inches *coal*.
No. 3 seam met with at . .	218	4 feet 11 inches *coal*.
No. 4 seam met with at . .	238	7 feet 3 inches *coal*.

(*b*) No. 26 boring has—

	Feet.	
No. 1 seam (top of) at . .	165	10 feet *coal*, 7 feet splint, 6 feet *coal*.
No. 2 seam met with at . .	235	29 feet 9 inches *coal*.
No. 3 seam met with at . .	347	5 feet 1 inch *coal*.
No. 4 seam met with at . .	358	7 feet 11 inches *coal*.

The proximate analyses of the coal and splint from these seams are given below from working sections:—

	Per cent.
No. 1 seam (top section 5 feet 6 inches)—	
Moisture	4·06
Volatile matter	30·80
Fixed carbon	51·05
Ash	14·09
Sulphur	0·79
Calorific value	7,187 calories.
Cakes, but not strongly.	
No. 1 seam (middle, splint, 5 feet 6 inches)—	
Moisture	3·68
Volatile matter	23·06
Fixed carbon	31·94
Ash	41·32
Sulphur	0·85
Calorific value	4,400 calories.
Does not cake.	
No. 1 seam (bottom section, 5 feet 6 inches)—	
Moisture	4·15
Volatile matter	27·52
Fixed carbon	49·87
Ash	18·46
Sulphur	0·43
Calorific value	6,600 calories.
Cakes, but not strongly.	
No. 2 seam (26 feet)—	
Moisture	4·40
Volatile matter	30·94
Fixed carbon	51·60
Ash	13·06
Sulphur	0·44
Calorific value	7,187 calories.
Cakes, but not strongly.	

No. 3 seam (5 feet 9 inches)—

Moisture	5·88
Volatile matter	31·30
Fixed carbon	53·03
Ash	9·79
Sulphur	0·31
Calorific value	6,600 calories.

Cakes, but not strongly.

No. 4 seam (7 feet 6 inches)—

Moisture	5·89
Volatile matter	25·65
Fixed carbon	48·70
Ash	19·76
Sulphur	0·23
Calorific value	5,867 calories.

Cakes, but not strongly.

These analyses, with ultimate analyses of these coals by Mr. C. S. Fawcitt, are given in the *Transactions of the Mining and Geological Institute of India*, IV, pages 134-135, (1909).

From the data given above, regarding the amount of coal extracted from the Gotitoria workings, and the available reserves, as estimated by Mr. F. L. G. Simpson in 1904, it is clear that barely one-sixth of the computed total has been taken out. And, seeing that sand stowing had been adopted in these mines (Plate 12), it is evident that either the cost of extraction had become abnormally high or a mistake has been made in closing down these mines. The coal in No. 1 (top section), No. 2 and No. 3 seams is clearly of good quality. And the thicknesses given with the analyses indicate reserves of roughly a million tons, four million tons, and a million tons respectively in these seams, in an area of 100 acres. This total of about six million tons would yield, allowing a third for losses from faults, intrusions and waste, four million tons of available coal, and deducting from this the million tons taken out in 25 years, at least enough to last another 25 years.

Further, there is this to be said that the area at Gotitoria was considered in two sections—A, that to the east to which all the mining operations have been confined; and B, an area of 150 acres, a mile west of A. Very little work, except boring and operations for opening a new colliery, has been carried out in area B. The strata appear to lie on a gentle anticlinal and are believed to be rather heavily watered. The geological evidence from

the borings shows that the Barakars had been subjected to erosion before the Bagra beds were deposited. However, in boring No. 38d, No. 1 seam (nine feet) was met at 52 feet, No. 2 seam (24 feet 7 inches) at 116 feet, No. 3 seam (4 feet 6 inches) at 213 feet with No. 4 seam immediately below it. But in boring No. 34 only a little of No. 1 seam is preserved at 44 feet, but No. 2 seam (27 feet) is present at 102 feet, and Nos. 3 and 4 seams were found at 185 feet. There is thus proof of the existence of a fair reserve of coal, estimated at not less than three million tons of workable coal, in this B area.[1]

Production of coal.

The annual production of coal from the mines at Mohpani on the Sitariva and subsequently from the collieries opened to the west at Gotitoria from the commencement of activities in 1860 to the closing down in 1927 are given in the table below :—

Year.	Tons.	Year.	Tons.
1860-1866	No information.	1880	9,401
1867	509	1881 (Total.) . . .	10,454
1868	1,384	Mohpani.	
1869-1871 (Total.) . .	6,594	1867-71	8,487
1870 (G. I. P. Railway despatched by.)	78	1872-77	81,186
		1878-82	67,299
1871 ,, ,, .	5,947	1883-87	94,164
1872 ,, ,, .	7,332	1888-91	59,837
1873 ,, ,, .	9,454	1890	5,529
1874 ,, ,, .	15,107	1891	18,067
1875 ,, ,, .	19,170	1892	(?) 19,000
1876 ,, ,, .	13,912	1893	(?) 20,000
1877 ,, ,, .	12,972	1894	(?) 21,000
1878 ,, ,, .	10,384	1895	21,393
1879 ,, ,, .	10,618	1896	19,542

[1] *Rec. Geol. Surv. Ind.*, LVII, p. 65, (1925).

Year.	Tons.
Mohpani—contd.	
1897	19,975
1898	22,472
1899	23,596
1900	39,612
1901	43,046
1902	43,645
1903	31,443
1904	26,618
1905	22,998
1906	27,503
1907	41,322
1908	48,241
1909	60,667
1910	39,484
1911	51,983
1912	56,857
1913	64,887
1914	59,774
1915	55,086
1916	48,395
1917	71,693
1918	78,792
1919	85,299

Year.	Tons.
Mohpani—concld.	
1920	83,335
1921	89,623
1922	84,990
1923	87,387
1924	76,526
1925	70,039
1926	71,482
1927	Abandoned.
Central Provinces.	
1890	137,022
1891	141,736
1892	132,005
1893	135,118
1894	140,495
1895	122,776
1896	141,185
1897	131,629
1898	149,709
1899	156,576
1900	172,842
1901	191,516
1902	196,981
1903	159,154
1904	139,027

Other Areas in the Northern Satpura Tract.

Exposures of Lower Gondwanas.

The search for coal along the northern margin of the Satpura Gondwana basin, which began with the discovery of Lower Gondwanas (Barakars and Talchirs) in the Sitarewa at Mohpani, has been continued since. The presence of Talchirs at the junction of the

Pathapani and Anjan streams, about two miles south of Fatehpur (22° 42′ : 78° 31′), and the report of the finding of coal fragments in the Anjan river, led to a search here; but so far no Barakar measures have been found. The next area to the west, where Talchir shales have been found, is that on the Piparia-Pachmarhi road, about mile eight from Piparia and east of Chauka (22° 38′ : 78° 23′). Here Deccan trap is found along the north, and Bagra conglomerate along the south, of the mile-broad strip of Talchirs. No Barakars and no coal have been found in the Ghogra *nala* section between the road and Chauka. As already stated on page 247, there is some doubt as to whether the coal, found at Pursapani in the lower Denwa valley, is of Damuda age at all. In Mr. Crookshank's opinion it is in the Jabalpur beds. Again, the coal of Ranipur is in doubt as to its true Damuda horizon. It is definitely accepted as of Damuda age, but we are not sure if it belongs to the Raniganj (Bijori) series or to the Barakars. In any case the evidence of these exposures has not been in favour of attractive seams of good coal.

Borings for Coal.

Between 1860 and 1879 a search for the concealed coal measures in the northern part of the Satpura-Gondwana basin was very thoroughly made by Mr. H. B. Medlicott; he left no point neglected, and was able to make his exploration by borings at all places promising the slightest possibility of success. Out in the alluvium of the Narbada valley at Ghagrola, Sukhakheri, Gadarwara, Bankheri and elsewhere, the borings did not penetrate the alluvium at depths up to 500 feet, and thus were not deep enough. Coal measures were proved near Patkuhi, east of Mohpani, but the results were evidently not encouraging although the extension of the Barakars was established. Again the borings at Tundni, ten miles west of Mohpani, although coal was found in No. 3 borings the other results were inconclusive. Next borings were put down in the Denwa beds at Khapa (22° 38′ : 78° 43′) and Manegaon (22° 37′ : 78° 42′), in the Dudhi valley to 720 and 420 feet respectively, but failed to get through the red rocks. This was also the case with the boring near the Piparia-Pachmarhi road. Finally, borings to a depth of 302 and 241 feet were also put down in the Tawa valley near Kesla (22° 28′ : 77° 51′) and near Suktawa on the Pachmarhi

beds without penetrating the former and merely continuing in the Bijori beds in the latter.[1] The coal in these Bijori rocks, as studied east of Suktawa, is of little economic value.

BETUL (SHAHPUR) FIELDS.

Sonada Coalfield.

The earliest discovery of coal in the Satpura region was made in 1827, in the Sonada area by Colonel J. R. Ouseley.[2] This area was exploited in 1848, when a consignment of coal was despatched to Bombay for steamer trials.[3] The Sonada area was examined in detail by Mr. H. B. Medlicott[4] and under his advice a number of borings[5] were put down in 1881; but, in spite of the fact that the coal measures were bored through, no seams of workable coal appear to have been proved.

Sonada (22° 16′ : 77° 49′) is situated on the Motur sandstones of the Middle Damudas, and the Barakars evidently occur in the Bhawra *nala*, just south of the village. They strike east and west and dip about 8° northward. Up the Bhawra *nala* towards Kuppa (22° 14′ : 77° 46′) three exposures of coal are to be seen, all of which are relatively poor. The sections in this stream are of interest, in that the Barakars appear to pass down conformably into the upper strata of the Talchirs. Thin coaly layers occur in typical Talchir rocks with plant impressions (leaves) characteristic of the Talchir (topmost) beds known as the Rikba stage of the Karanpura field.[6]

The Sonada area was visited by the author in 1932. In his opinion the exposures and data available do not provide enough evidence to justify a final unfavourable opinion. It is possible that the Barakars, as a coal-measure series, are less attractive in this area than is normal. It is also to be remembered that outcrop exposures of good seams are often very unattractive. Furthermore, the thickness of coal seams, as proved by the older methods of drilling, was generally as discouraging as the assays obtained

[1] *Rec. Geol. Surv. Ind.*, VIII, p. 69, (1875).
[2] *Jour. As. Soc. Bengal*, III, p. 395, (1834).
[3] *Sel. Rec. Bom. Govt.*, XIV, pp. 27-115, (1848).
[4] *Rec. Geol. Surv. Ind.*, VIII, p. 82, (1875).
[5] *Op. cit.*, XVI, p. 2, (1883).
[6] *Mem. Geol. Surv. Ind.*, LVIII, p. 222, (1931).

from such bore-hole samples. On the whole, however, I am of the opinion that the Sonada area cannot be finally neglected until a modern boring to a depth of 750 feet is put down in the banks of the Bhawra *nala*, immediately south of Sonada.

Suki River or Gurgunda Area.

The Sonada area is separated from the next area of Barakar coal-measures, to the east, by a crush zone (due to faulting) trending west-south-west from the Tawa river near Dhodra Mohar (22° 17′ : 77° 53′), barely five miles from Sonada. In fact, the Sonada coalfield is sometimes considered as one of the Shahpur coalfields. There are three areas of Barakars, respectively north, north-east and east of Shahpur (22° 12′ : 77° 54′) in the valley of the Tawa, which are here referred to as the Shahpur coalfields. These are the Gurgunda (22° 17′ : 77° 54′) or Suki-Kusmari area, the Mardanpur (22° 14′ : 77° 56′) or Machna River area, and the Katasur (22° 11′ : 77° 59′) or Golai *nala* area.

Production of coal.

Immediately after the War (1919) when the price of coal was high and the demand active, efforts were made to develop several of the areas in the Shahpur field where outcrops of coal were known—in the Suki or Gurgunda area, Mardanpur and the Machna river; and further away at Dulhara and even Patharkhera. For a time an output was maintained from these several localities and the total production grouped as Shahpur coal. These details are given below :—

Year.	Tons.	Year.	Tons.
1921	210	1925	1,119
1922	1,069	1926	423
1923	2,063	1927	6
1924	1,111		

The Barakars of this area form a narrow strip about 1¼ miles wide, south of the Tawa river, near the village of Gurgunda, where coal has been worked in a shallow incline. The coal measures strike east and west and dip north to the Tawa, where they are evidently cut off by a strong fault throwing northward. On the north bank of the Tawa the rocks are regarded as Moturs, and are traversed by a large dolerite dyke, which runs parallel with the river. The Barakars of Gurgunda extend from west of the Suki

nala to beyond Kusmari. They are cut off to the south by an east to west fault, south of which the Talchirs are seen. Between Gurgunda and Kusmari there are strong dolcrite dykes which must spoil the measures.

From the evidence available in the Suki section, the seams of coal are thin, except on the strike of the beds close to the Tawa. This will mean a very small productive area, unless coal can be proved in workable seams at a small depth, on the north side of the Tawa towards Gawari (22° 18′ : 77° 54′). As this location is more or less on a line of strike through Bhawra, near Dhodra Mohar railway station, it would be simpler to put a trial boring down on the banks of the Tawa in this vicinity. East of Kusmari the river section is not very clear, but in the Bharanga *nala* south of Chichidol (22° 16′ : 77° 58′), the strata seen are suggestive of Barren measures rather than Barakars.

Machna River or Mardanpur Area.

The Machna flows eastward past Shahpur, to join the Tawa south-east of Mardanpur. North of this stream a strong north-east fault brings in the Barakars to the south. In this Machna area coal has long been known and worked in a small way for short periods. From the position of the outcrops along the Machna, and the disused inclines, and other excavations, it is clear that the extraction of the coal would be difficult, even if the coal was attractive in quality and thickness. Efforts made north of Shahpur in the stream south of hill 1,593 feet (22° 12′ 30″ : 77° 55′); north of Kotmi (22° 13′ : 77° 56′); south of Mardanpur; and near Temru (22° 13′ : 77° 58′) have all proved useless; the beds are disturbed by faults or cut by dolerite dykes, and the workings are wet.

The most suitable place for exploration would seem to be a mile east of Mardanpur near Daori, and perhaps across the Tawa, a mile south of Malwar (22° 14′ : 77° 58′). It is almost certain that in both these places the Moturs overlie the Barakars, so that the coal seams will be relatively deep. It has still to be proved that the seams under these areas are good enough to work. So far as could be ascertained from the workings north of Kotmi and south of Mardanpur, the chief seam is barely five feet thick and the coal is unattractive in quality.

Golai *Nala* or Katasur Area.

Coal outcrops in thin seams have been met with in the Golai *nala* north of Katasur, but none of the exposures gave any hope of the existence of workable seams. An examination of the Tawa section east of Silpati proved less encouraging. There are several faults in this area, and one or two dolerite dykes further complicate matters. The area as a whole lies east of the Tawa river, so that, even if coal was proved by boring, say, at Golai (22° 12′ : 77° 59′), the question of working would be complicated by difficulties, due to dykes and faults, as well as to transport over the river to Shahpur (Barbatpur railway station).

Dulhara Coalfield.

This little area of about 1½ square miles of Barakar rocks lies across the Tawa river at Dulhara (22° 10′ : 78° 1′), 2½ miles north of Ghordongri railway station. There are disused workings in the ravine between the village and the little hamlet, half a mile to the east. Here the measures dip south-east and the coal cannot be more than five feet thick, if as much. The same seam is seen down the ravine and in the Tawa river below the dolerite dyke. In the Tawa river four coal outcrops have been recorded, but in no case was any thick seam met with. On two or three occasions this area has been opened up, but without the anticipated success of establishing a working colliery. The area is traversed by the Tawa river and enclosed by faults; to the north and east younger rocks appear; to the south and west Talchirs are seen.

South of the Tawa in the Dulahra field, a few borings were put down to depths of about 50 feet, in various places, and one seam of six feet of coal was proved. The quality is said to have been suitable for steam raising purposes, but no details have been furnished. In this case unfortunately the boring was close to the Tawa river, and as operations were closed down for several years it would seem that working was difficult. In any case, the evidence shows that the seams are somewhat better in the Dulhara area than in the Machna and Sonada areas.

Pathakhera Coalfield.

This area of about 16 square miles of Barakar rocks lies in the Ranipur reserved forest, south of the Tawa river, with the village

of Pathakhera (22° 6′ : 78° 10′) at its south-east corner. A narrow strip of Barakars connects the Pathakhera field with that of Dulhara, 5 miles to the west. A dolerite dyke trending east to west forms the north-east boundary of the Pathakhera field from the Tawa river. The field is traversed by several dolerite dykes and the strata are disturbed along the eastern margin; in the north Moturs are in force; and in the east and west Talchirs. Towards the south Talchirs and gneisses are faulted against the coal measures. However, the country is not difficult between Pathakhera and Ghordongri railway station, 12 miles to the west.

Coal appears to have been first discovered in 1867 in the vicinity of Pathakhera by Major J. Ashburner who called it the Mordongri seam. The field was examined by Mr. E. J. Jones[1] about 20 years later, and the area was again visited in 1924-25 by Mr. E. R. Gee[2] who wrote as follows:

'This Pathakhera area, therefore, appears to represent a large tract which promises well to exploiters, certainly the most promising tract, so far as our present knowledge goes, of the Tawa valley coal-bearing strata; and considering its nearness, 7 to 10 miles, from the Betul-Itarsi railway, it is surprising that the question of its exploitation has not already been taken up more enthusiastically.'

The following particulars have been very kindly communicated to the author by Mr. C. S. Harris, who held the leases of the area at the time of Mr. Gee's visit. In the Pathakhera vicinity two borings, Nos. 1 and 2, were put down, which proved three seams of coal—4 feet 8 inches at 173 feet; six feet at 243 feet; and 14 feet at 314 feet. These seams outcrop in the area, and show that the 14-foot and six-foot seams are of fair quality, while the top seam is poor. Further to the north, on the banks of the Tawa river, a boring (No. 4) proved the 4-foot 6-inch seam at 113 feet, the six-foot seam at 166 feet; and the 13-foot seam at 213 feet. To the north-west of No. 1 boring No. 3 boring proved these three seams as follows—3 feet 10 inches at 286 feet; six feet at 359 feet; and 13 feet at 437 feet. Further west the seams encountered were thinner; but this area has not been properly proved.

Mr. Harris' information was not available to Mr. Gee and the exploration was made before the construction of the Betul-Itarsi railway. Nevertheless, Mr. Gee also found three seams of coal, the thickest being about ten feet, but the beds in the exposures

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 43, (1887, reprint 1924).
[2] Unpublished report.

studied were obviously disturbed. Unfortunately no analyses of the coal are now available, and it must be concluded that the coal was only of fair quality. With this data and caution as to quality, it is still true to say that the Pathakhera area is the most promising of the coalfields in the Betul district. As to the quantity of coal, it may be safely taken that, in the ten-foot seam, there will be 10,000,000 tons per square mile. Allowing a loss of 50 per cent. for dykes and faults, and loss of coal in working, the available coal is 5,000,000 tons per square mile; and three square miles can be taken as more or less proved. Thus 15,000,000 tons of fair quality coal may be looked on as the available reserves in the south and eastern area of the Pathakhera field.

Bamhanwara-Khapa Area.

The Barakar strata of the Pathakhera area extend from the north-east corner of that field across the Tawa river to Baghdeo Pahar (22° 10′ : 78° 12′) with westerly dips under the tract of Bogai-Khapa. To the east Talchirs occupy an extensive area about the villages of Bamhanwara (22° 8′ : 78° 13′) and Khapa (22° 9′ : 78° 14′). An outcrop of coal had been noted by Major Ashburner in 1866 in the Tawa south-east of the present village of Photidhana (22° 9′ : 78° 10′); and in 1931 I found coal outcrops of thin seams in the stream just along the eastern base of Baghdeo Pahar. The area of Barakar rocks is roughly two miles by a mile, and has not been prospected fully. This area involving Baghdeo Pahar may be spoken of as the Bamhanwara area, although the village lies east of it on Talchirs.

North of the village of Khapa, between Bamhanwara and the hamlet of Rajegaon, nearly all the streams draining from the glens on the southern side of Sirri Pahar (22° 12′ : 78° 14′) show small fragments of coal in their alluvial debris. The Barakar rocks, from which these pieces are derived, are seen in the base of the slopes as well as in the hills north-east of Rajegaon. No coal was found *in situ* by the author, and the beds are clearly disturbed by faulting. Nevertheless, as the overlying Moturs show south-easterly dips in this area, it is an interesting point whether the coal measures may not be met with, at a shallow depth, under the younger rocks in the upper valley of the Dagdaga *nala* at the south-west base of Kilandeo Hill (22° 14′ : 78° 14′). It is known, for example,

that Barakars occur in the deep valley of the Baradha *nala* south-east of Kilandeo.

Upper Tawa Valley.

From the north-east corner of the Pathakhera field, west of Bamhanwara, the Tawa river flows on Talchir rocks from its source south of Haryagarh or Hirdagarh (22° 8′ : 78° 29′). The dips of these rocks are gently northward, so that the Barakars and overlying Moturs occur in the hills to the north. It is in the tributaries draining from these hills that the coal outcrops, now to be mentioned occur. The coal exposures in these valleys were mentioned by Mr. E. J. Jones, but were evidently first reported in 1866 by Major Ashburner.

Chikhalmau.

Coal fragments are found in the Baradha valley above Akori (22° 10′ : 78° 16′), but these may come from two exposures higher upstream. Two such outcrops are shown on Mr. Jones' map below the junction of the little nala from the east, from below Bakhari (22° 13′ : 78° 18′). Both sites are in the Baradha *nala*, within a mile south-west of the deserted village of Chikhalmau (22° 13′ : 78° 16′). Very few details are available, and when in 1925 Mr. E. R Gee visited them, the exposures were obscure.

Mr. Jones also mentions thin strings of coal in an exposure, north-west of the now deserted village of Umardoh (22° 9′ : 78° 18′); the exact locality must be a mile or so E. N. E. of the present village of Danwan (22° 9′ : 78° 17′).

Tandsi.

In the next important tributary of the Tawa, the Tamia or Tanbia, the following section is said to have been observed above the present village of Tandsi (22° 12′ 30″ : 78° 20′ 30″) :—

	Feet.	Inches.
Surface soil	12	0
Coal	5	0
Carbonaceous shale	1	6
Coal	2	0
Carbonaceous shale	0	4
Coal, over	0	6

The discovery is credited to Major Ashburner. The exposure is complicated by faulting and is now obscured; it would be very difficult to work, and the place is not easy of access.

Potia *nala*.

No coal appears to have been reported between the Tanbia and Potia *nalas*, nor between this tributary of the Tawa and the watershed near Kalichhapar, where coal has been proved in the Kanhan drainage area. As already stated, the country is difficult, and the presence of strong faults, and the cover of Moturs on the hills will restrict search to boring in the valleys to get coal at shallow depths under the younger rocks. Had the railway connecting Betul with Parasia been carried up the Tawa valley, instead of along the crystalline plateau to the south, this area might have received further attention. It is not likely to do so now for very many years until the area is made more accessible. It is in fact less accessible now than it was before the railway was constructed from Amla to the Pench valley. All the cart-tracks are now almost useless.

[1] *Mem. Geol. Surv. Ind.*, XXIV, pp. 40-43, (1887, reprint 1924).

CHAPTER 15.

COALFIELDS OF THE CENTRAL PROVINCES—*contd.*

SATPURA GONDWANA BASIN AND COALFIELDS—*contd.*

SATPURA COALFIELDS—*contd.*

KANHAN VALLEY COALFIELDS.

This title is used for the known coal outcrops of the large area which extending from the Kanhan to the Pench valley. Some of the coal exposures in the eastern end are part of the Barakars which might strictly be included the Pench Valley field. However, it is best to treat these areas according to the drainage system of the whole; those which belong to the Kanhan river are included in the Kanhan group of fields, while those in the Pench will be discussed under the Pench Valley coalfield. Among the areas in the Kanhan coalfield will be included—(*a*) The Kalichhapar and Damua areas; (*b*) the Ghorawari-Nimkhera area; (*c*) the Panara-Jinaur area; (*d*) the Datla-Jamai area; (*e*) the Jamkunda area: and (*f*) the Dow Forest or Hingladevi area.

Damua-Kalichhapar Area.

The main village of Damua (22° 12′: 78° 28′) is situated on the west bank of the Kanhan, on Barakar rocks, faulted against Talchirs to the south. The Barakars trend east and west and are traversed by at least two strong strike-faults. They dip northward, and north of Damua, the outcrop must be over a mile wide. Beyond the Barakars to the north the Moturs or Barren measures overlie them. Coal occurs south of Kalichhapar a mile north-west of Damua, where exploration shows that the coal, although thin at the cutcrop, increases in thickness to the dip. In the inclines, the seam which dips gently northward is nine feet thick, while a boring to the dip gave 15 feet of coal. Half a mile north of Kalichhapar, a strong fault throwing south cuts off the seam, which at the fault must be at a depth of 500 feet. The seam must be much closer to the surface to the north of the fault; but, as the throw of the fault is not proved, it is difficult to say how much nearer to the surface the seam may be. No analysis of the coal is available.

Mr. G. V. Hobson tested some of the coal from the incline and found it was not of caking quality. He expressed the opinion that this did not prove that there was no caking coal in this vicinity.

There are at least three exposures of coal near Damua. One of these on the east bank of the Kanhan river has been opened by inclines in the area of the Kanhan Colliery. The coal here is about 14 feet thick, but at the time of Mr. Hobson's visit he could see four feet of mush coal above 5 feet 8 inches of hard coal, and the bottom of the seam was not visible. The area is faulted, and a strong fault runs south of the inclines along the strike (east-west) of the beds, bringing Talchirs in to the south. To the north, red clays and sandstones of the Moturs appear. The coal is of interest as it is of caking quality. Mr. Hobson's[1] analyses show:—

	Per cent.
Moisture	2·44
Volatile matter	30·76
Fixed carbon	49·58
Ash	17·24
Calorific value	6,515 calories.

while the hard coke obtained yielded:—

	Per cent.
Moisture	0·24
Volatile matter	0·48
Fixed carbon	73·56
Ash	25·72

Efforts to find this seam by borings between Damua and Ghorawari have so far proved disappointing owing to faults. The outcrop of the seam has been found, however, but it is cut off to the dip by a fault, evidently throwing north. This fault may also cut off the Damua seam to the dip, and may be responsible for the appearance of the Moturs, so close along the north of the main Damua outcrop.

Ghorawari-Nimkhera-Kolhia Area.

This tract of Barakar rocks is the eastward continuation of the Damua outcrop. There are three strike-faults, including the strong one along the south, which brings in the Talchirs in that direction. The Damua fault passes north of the present workings of Ghorawari

[1] *Rec. Geol. Surv. Ind.*, LIX, p. 184, (1926).

Colliery, and a show of Talchirs above this fault, in the *nala* that comes down from west of Kothideo (22° 12′ : 78° 17′) suggests that the fault throws southward. The main seam of Ghorawari Colliery can be traced from just south of Ghorawari Khurd (22° 11′ : 78° 15′) to south of Puraina (22° 11′ : 78° 16′), where a fine ridge of fused and baked shales, marking the burnt outcrop, continues the trace as far as Nimkhera (22° 11′ : 78° 17′). This seam must be about 15 feet thick, although only eight feet are evidently worked. The coal was sampled and tested by Mr. Hobson, who found it to be of caking quality. His results are as follows:—

	Per cent.
Moisture	2·40
Volatile matter	28·66
Fixed carbon	50·14
Ash	18·80
Calorific value	6,348 calories

and the constitution of the hard coke obtained:—

	Per cent.
Moisture	0·12
Volatile matter	0·84
Fixed carbon	71·40
Ash	27·64
Sulphur (from specimen)	0·71

Other analyses carried out for the company by Messrs. R. V. Briggs showed a lower percentage of ash and a higher calorific value.

A small seam evidently occurs above this main seam and is exposed by the road, just north of Puraina village, in two or three disused inclines. There are also two seams below the Ghorawari seam—a ten foot seam below 15 feet of sandstone under the main seam, and the bottom seam—ten feet with 45 feet of sandstone—between it and the one above. These lower seams and the sandstone partings are variable, as Mr. Hobson gives lesser thicknesses for all the measurements. There are two exposures of coal seams in the Ghorawari *nala* west of the present mines. One occurs just south of a strong fault, half a mile south of Ghorawari Kalan, and the other lower down stream, south of the dolerite dyke and about west of Ghorawari Khurd; and two smaller seams are exposed in the next *nala* west of the lower exposure. The main Ghorawari seam must be below the seam west of Ghorawari Khurd,

but it is difficult to fix the horizons of the seams further west. It is thought that the Damua seam is the same as the Ghorawari seam, but changed in position by faulting.

In the glen below Kothideo and between this village and Puraina, the Ghorawari seam was again encountered and opened by inclines; but the seam is cut off to the dip (north) by a fault, and found again beyond the fault in a higher position, showing that it extended northward under Kothideo village. A burnt outcrop half a mile north-east of Nimkhera, which dips into the same glen, may represent a lower seam or the one above mentioned. It is thought that the strong fault, seen in the hill north of Puraina, with a throw to the south, lifts the Ghorawari seam on the north side into the position of the seam below Kothideo. Mr. Hobson's analysis of this coal estimated at about 12 feet is as follows:—

	Per cent.
Moisture	1·94
Volatile matter	27·58
Fixed carbon	51·32
Ash	19·16
Calorific value	6,371 calories'

It yields a hard coke.

The same seam appears to be present further east, in the valley west of Kolhia. The seam near Kolhia, owing to the inclines being full of water, is now not seen. At the time of my visit in 1924 the section in No. 1 incline showed 14 feet of coal. According to Mr. Hobson, a basket full of the coal, cut from a part of the seam which is visible, gave a fairly hard coke. The analysis of this basket of coal gave:—

	Per cent.
Moisture	4·31
Volatile matter	27·16
Fixed carbon	49·16
Ash	19·34
Calorific value	6,194

The higher moisture content would fully explain the effect on the caking quality and also the slightly lower calorific value.

Panara-Jinnaur Area.

Panara (22° 13′ : 78° 33′) is less than a mile north-east of Kolhia, but separated from it by one fault and at least three dolerite dykes,

all parallel with the strike of the beds. The waterfall west of Panara drops over a massive sandstone, at the base of which, in the pool, a seam of coal is exposed. As the red calcareous clays of the Moturs occur immediately north of Panara, it is thought that either a fault passes behind the village (north of) or that this Panara seam is the topmost seam of the Barakars. It is difficult to decide; but, from a study of the area, I was inclined to believe that the seam is different from that of Kolhia, Kothideo, and Damua and is known as the Ghorawari seam in those places. It was known that a seam (or seams) occurs above the Ghorawari seam and so it seemed probable the Panara seam might be one of them. With this opinion Mr. Hobson also agreed, as he was unable to make coke with the Panara coal which is non-caking in quality. And the covering of massive sandstone is a new characteristic. However, after a careful study of the sections and boring records I concluded that the Panara seam is the same as the Ghorawari seam.

This Panara seam is evidently the same as that found in the nala, halfway between Panara and Jinnaur (22° 13′ : 78° 35′) flowing into the Panara or Takia nala, just north-east of Dongaria; it is undoubtedly the same seam as that worked near Jinnaur (at Junnor Deo Colliery). Here the dips are steeper than at Panara, but the dyke south of Panara has crossed the seam halfway to Jinnaur, where it is north of the seam outcrop; yet the Jinnaur seam (? same as the Panara seam) is about 14 feet thick of which 8 feet 6 inches are worked. Mr. Hobson's analysis of this section at Junnor Deo Colliery is:—

	Per cent.
Moisture	3·76
Volatile matter	29·80
Fixed carbon	39·96
Ash	26·48
Calorific value	5,226 calories.

The sample is on non-caking quality.

The Panara seam was visited in 1866 by Major Ashburner and was considered to be at least eight feet thick. Since his day the seam has been opened and found to be similar to that of Jinnaur. Also the same seam has been opened halfway between Panara and Jinnaur, and proved to be about 14 feet thick, but in this locality it is cut by the dolerite dyke. North of Junnor Deo Colliery the

red clays with calcareous nodules of the Barren measures show up, as at Panara, and there seems to be no fault until near the base of the hills to the north. Similar conditions were noted at Damua, so that it is probable that the Panara seam and that of Damua are not different. Eastward from Jinnaur no coal has been found, but it is possible that an E. N. E. fault, south of Jinnaur trending towards Kolhia (Kolia), cuts off the outcrop to the east, and the seam may be present at no great depth under, but north of, Chikhalmau (22° 13′ : 78° 36′), and also in a similar position near Aliwara a mile further eastward. It must be remembered, however, that there is another fault along the base of the hills.

Datla-Jamai Area.

The hill of sandstones north-west of Jamai (22° 12′ : 78° 35′ 30″) is of interest. The rock closely resembles the stone overlying the Panara-Jinnaur seam; also it is on the strike of the similar sandstones of Kolhia. The fault which cuts off the seams south of Kothideo would appear to be the same as that which passes south of Jinnaur. There are two cross faults at Jamai Hill, which dislocate the sandstones. No prospecting appears to have been done near (north of) Jamai, so that, until a boring is put down in this locality—say, in the *nala* immediately west of the northern end of Jamai—it is not possible to say if the Panara-Jinnaur seam has been faulted into this position. If such a seam is found it will go a long way towards proving that the Jinnaur seam is the same as that of Datla (and also of Kolhia and, consequently, as the Ghorawari seam). It is now well known that a seam may be of caking quality in one place and not in another close by.

There is a fault trending E. S. E. between Jamai and Junnor Deo railway station on the G. I. P. Railway. This is proved by the red clays of the Barren measures north of the station. South of the railway station, there are Barakar sandstones with a seam of coal below them, in the same position as the coal of Panara and Jinnaur. Several inclines have been made in this coal which dips northward at a gentle angle. It is difficult to examine the seam, but it is about ten feet thick or more. To the south a strong fault cuts off the Barakars and brings in the Talchirs at Swami Khapa (hill; 22° 11′ : 78° 35′). There is no doubt at all that this seam, south of the railway station, is the same as that at Datla.

Mr. E. J. Jones [1] found the Datla seam near the deserted village of Badhi (Badeo) and in the Takia *nala*. He states that it had already been seen in 1866 by Major Ashburner and again in 1867 by Mr. A. Sopwith. Lower down stream he found three seams. or four in all, in this vicinity at short distances (40 to 50 feet) apart, We are now assured that the series is the same as that of Ghorawari, although the outcrops naturally give smaller thicknesses than a bore-hole section might give. Dongaria colliery is situated in this locality, *i.e.*, between the Takia nala and Dongaria village (22° 12′ : 78° 34′), now deserted. The seam met with here is that of the Badhi exposure. Mr. Hobson took a sample from the Badhi workings and selected some coal from Dongaria; in both cases the coal was of caking quality with coke as hard and silvery as that from Ghorawari. His analyses are as follows :—

	Per cent.
Coal from Badhi :—	
Moisture	4·56
Volatile matter	29·84
Fixed carbon	42·46
Ash	23·14
Calorific value	5,602 calories.
Coke from Dongaria :—	Per cent.
Moisture	2·18
Volatile matter	3·02
Fixed carbon	70·62
Ash	24·18

It is thus seen that the Dongaria coal must be of better quality than that of Badhi. It is also of interest that we are clearly dealing with material similar to that of Ghorawari.

Mr. Jones[2] has given analyses of outcrop samples from the top seam in the Takia near Datla, from the seam next below, and from the seam between Datla and Badhi. This last gave only 17·72 per cent. of ash and is probably the seam we have been discussing above. Mr. Hobson is evidently in no doubt that the seam at Datla and that at Badhi, halfway between Datla and Dongaria, are one and the same. The Badhi and Dongaria seams are also correlated with each other. It is not to be forgotten, however, that there are at least two seams below this important upper one,

[1] *Mem. Geol. Surv. Ind.*, XXIV, p. 38, (reprint 1924).
[2] *Op. cit.*, p. 54.

but these appear to be of poorer quality, so far as present data go. Messrs. Shaw Wallace and Co. are working at Datla and have put down borings to the dip of the seam in the valley to the north, through the red clays of the Moturs. The coal seam at Datla may be taken as ten feet thick and of the same quality as at Badhi. There is, in my opinion, no fault between the covering sandstones of the Datla seam and the Motur clays in this locality. As silicified fossil wood is of common occurrence in association with these clays and a sandstone just above them about Panara, Jinnaur, Jamai and Datla, a very useful guide is secured. The conformability of these clays on the Barakars, and the fact that the top workable seam is only 150 to 200 feet below the base of the clays, will be an encouragement for future exploration, by borings through the clays in search of coal.

Hingladevi or Ghogri Area.

Although the Barakars south of Junnor Deo railway station are cut off to the east, and the Motur red clays are brought against the Talchirs along the south boundary fault, south of Sukri (22° 12′ : 78° 37′), the Barakar sandstones are in force along the ridge which runs east through Jamkunda (22° 11′ 30″ : 78° 38′) to Ambara (22° 11′ 30″ : 78° 41′). From this village they continue into the Barkuhi area of the Pench Valley field, and also southward into the Dhow forest west of the village of Ghogri (22° 10′ 30″ : 78° 42′). The whole of the area, from Jamkunda and Ambara to the Dhow forest, is called for convenience, the Hingladevi area, but the Jamkunda-Ambara ridge belongs to the same sweep of rocks as passes on to Barkuhi. The word *hinglaj* in the language of the Gonds means coal, and the little shrine of Hingladevi appears to be somehow connected with coal[1] in the minds of the Gonds. So it is evident that this area has long been known to contain coal. It is not unlikely that this is one of the areas in which coal was found by Dr. Jerdon and Lieutenant R. H. Sankey[2] about 1852. The area was also examined by Dr. W. T. Blanford[3] in 1866.

The coal in the Dhow forest is exposed in the stream flowing west from Ghogri, and the coal measures pass under the basalts

[1] Jones, *op. cit.*, p. 35.
[2] *Q. J. G. S.*, X, p. 55, (1854).
[3] *Rec. Geol. Surv. Ind.*, XV, p. 134, (1882).

of the Deccan trap to the south and east. Dr. Blanford thought the seam was above five feet thick and of fair quality. Exploration has been made in two places—East Ghogri Colliery, a mile west of Ghogri, and No. X colliery in the spur a mile south of Ambara. Mr. Hobson[1] examined these workings during his sampling operations of the Pench Valley coalfield in 1924; he found the seam in the former workings to be 5 feet 9 inches thick. The coal is of non-caking quality and give the following assay:—

	Per cent.
Moisture	6·10
Volatile matter	28·22
Fixed carbon	41·84
Ash	23·84
Calorific value	5,372 calories.

The seam in the other (X colliery) workings was also sampled over the full section there—5 feet 5 inches—and was non-caking in quality, the analysis being:—

	Per cent.
Moisture	4·90
Volatile matter	30·70
Fixed carbon	42·68
Ash	21·72
Calorific value	5,638 calories.

All future exploration of this tract must be under the Deccan trap to the east and south. The Talchirs appear from beneath the Barakars to the west. Indurated Barakar sandstones appear from beneath the trap, a mile to the south of Ghogri at Moari, and extend in a thin strip westward along the line of a strong fault, south of which gneisses occur. These indurated sandstones can be traced for over a mile to beyond Khari (22° 9′ : 78° 40′). There would thus be at least one square mile of Barakars under the trap south-west of Ghogri.

Several borings have been put down both on the ridge of Barakar sandstones between Jamkunda and Ambara, and in the area to the north, south of Palachauri (22° 12′ : 78° 40′), where the red Motur clays are in evidence. A fault trending east to west follows the north side of the ridge, bringing in the Moturs. This boundary is further complicated by a dolerite dyke, which runs somewhat

[1] *Rec. Geol. Surv. Ind.*, LIX, p. 179, (1926).

oblique to the fault and crosses it near Nazarpur. It is not certain if the dyke is faulted or is newer than the fault. To the south of the ridge Talchir rocks show from under the Barakars, which dip gently northward. The evidence of borings indicates that the whole of the Barakars are not present on the ridge, and that the top or main seam has been removed by erosion near Jamkunda. It is possible that it is represented by a six-foot seam near Ambara and in the valley west of Ghogri.

The boring explorations show that there are four coal seams with coaly shale partings, and all under five feet thick. Workings opened on the ridge near Nazarpur, and again south-west of Pipraj (north-west of Ambara), and just south of Ambara, have proved a top seam of 5 to 6 feet, and three seams below of four feet and less. The dips are northward to north-east (near Ambara). There are two cross faults between Nazarpur and Ambara, and a strong east-north-east fault south of Ambara. The area of coal bearing ground, south of the Nazarpur-Ambara fault, is thus narrow and difficult with no specially attractive seams. Borings along the northern side of the fault have shown that the coal measures must lie at depths of 200 to 400 feet.

Estimates of Coal in the Kanhan Areas.

From the data given in the preceding pages, it is seen that the whole tract is sliced by parallel faults, trending north of east and south of west, and that, although three or four seams of coal of workable thickness are present, only one, the top seam, is both thick and of good enough quality for profitable exploration. This seam is believed to be the same as that worked at Damua, Ghorawari, Datla (Badhi) and Junnor Deo collieries; it seems to be thinner to the east about Ambara, if the top seam there is the same. As seen from the analyses made for Mr. G. V. Hobson, the coal is of fair quality, but not equal to the first grade coals of the Jharia and Raniganj coalfields. Each coal property is generally faced with the problem of working a narrow strip of coal-bearing ground lying between parallel faults; and, though the faulting lifts the coal to the north (in the Ghorawari and Jinnaur areas), the reverse is often true (Nazarpur and Ambara). It is difficult to estimate the amount of coal available, as the allowance for losses must be calculated at a much higher percentage than usual. Although the

caking character of much of the Kanhan coal is now well known, little has so far been done to make coke or so-called soft-coke in this area.

PENCH VALLEY COALFIELDS.

The discovery of coal in the area known as the Pench valley is credited to Dr. Jerdon and Lieutenant R. H. Sankey, who visited the area about 1852. They were followed shortly after by Messrs. Stephen Hislop and R. Hunter.[1] The first geological traverse was made in 1856 by Mr. J. G. Medlicott. Further discoveries were made by Major Ashburner in 1866 when the area was examined by Dr. W. T. Blanford.[2] Mr. A. Sopwith[3] visited the field in 1867 and made an estimate of the quantity of coal. The whole area was surveyed by Mr. E. J. Jones[4] in 1884-86. Captain Leslie Ditmas[5], the first manager of the Pench Valley collieries, who was engaged in opening up the field, wrote a brief summary of the conditions in his time over 20 years ago. Mr. G. V. Hobson[6] carried out an elaborate series of sampling operations in 1924 and the area has been re-surveyed by Mr. W. D. West and Dr. C. S. Fox between 1923 and 1925.

The area involved lies in the drainage of the Pench river north-west of Chhindwara (22° 3′ : 78° 56′), and between 22° 9′ and 22° 14′ north latitude and between 78° 40′ and 78° 55′ east longitude. The most important company engaged is Messrs. Shaw Wallace & Co. of Calcutta, to whose efforts the development of this area, especially in the early years of the present century, is largely due. the Bengal-Nagpur Railway in 1905 extended their narrow-gauge line (Nainpur-Chhindwara branch) from Chhindwara to Barkuhi (22° 12′ : 78° 42′), and at the same time contemplated a branch from Khirsadoh (22° 10′ : 78° 47′) to Sirgora (22° 12′ : 78° 53′). The first colliery was opened at Chandameta near Parasia in 1905 by Messrs. Shaw Wallace and Co. The line between Chhindwara and Nagpur was opened by the Bengal-Nagpur Railway in 1912. Finally, in 1915 during War, the Great Indian Peninsular Railway

[1] *Q. J. G. S.*, X, p. 55, 1854 ; and XI, p. 556, (1855).
[2] *Rec. Geol. Surv. Ind.*, XV, p. 121, (1882).
[3] *Trans. Manchester Geol. Soc.*, VII, p. 32, (1867).
[4] *Mem. Geol. Surv. Ind.*, XXIV, (1887).
[5] *Trans. Inst. Min. Eng.*, XLI, p. 133, (1911).
[6] *Rec. Geol. Surv. Ind.*, LIX, p. 165, (1926).

extended their broad-gauge line from Amla (near Betul), through the Kanhan area about Jamai, to the Pench valley at Parasia (22° 12′ : 78° 46′), where transhipment to the Bengal-Nagpur Railway narrow gauge is possible.

For convenience of description, the Pench Valley coalfield is best treated in small areas from west to east. A continuous strip of coal measures (Barakars) trends eastward from Barkuhi through Chandameta and Parasia to the Pench river near Chhinda (22° 12′ : 78° 51′). Next there are disconnected areas of Barakars in various places—a mile north of Gajandoh (22° 9′ : 78° 44′); eastward from Eklaira (22° 12′ : 78° 42′) to the north-east slope of Chandameta hill; near Harrai (22° 11′ : 78° 48′); near Setia (22° 13′ : 78° 51′); at Sirgora (22° 12′ : 78° 53′); and near Haranbhata (22° 12′ : 78° 54′). The areas most actively exploited at present are those between Barkuhi and Rawanwara (22° 12′ : 78° 48′) and the strip eastward from Eklaira. For the past ten years no work appears to have been done elsewhere in the Pench Valley coalfield. The construction of the line from Khirsadoh to Sirgora has been discontinued, and the cuttings and culverts are now overgrown.

Geology.

From the point of view of the student of Indian geology, the area in and around the Pench Valley coalfield is as interesting as any in the Central Provinces. The rock formations met with comprise the following, in descending order of superposition:—

Alluvium of the Pench river west of Chhinda.

Deccan trap flows capping the hills and dykes of basalt (dolerite) near Khirsadoh, Parasia, and other places, including the workings in the mines.

Infra-trappean grits south of Khirsadoh and east of Harrai, and the red jasper pebble beds at Haranbhata. These conglomerates are possibly representatives of the highest Upper Gondwana beds, but it is not possible to fix their age without fossil evidence.

Moturs (equivalent to the Barren Measures or the middle division of the Damudas in the Damodar valley), which consist of soft yellowish coarse sandstones and red clays with calcareous nodules and also mottled and buff clays. These beds are seen south-east of Rawanwara, near Chandameta, and cover extensive areas north of Barkuhi

and Eklaira. They are known to be conformable to the Barakars and are well developed in the Pench river upstream from the Chhindwara-Tamia motor road. Silicified fossil wood is occasionally found above the clays and below the sandstones. The thickness of these beds must be upwards of 2,000 feet, but as the dips are northward only the lower strata are seen in the Pench valley area.

Barakar or coal measures, which constitute the main storehouse of coal in India, here consist of coarse sandstones, carbonaceous shales, grey shales, and seams of shaly coal, and good coal. Although several seams of coal occur, only four of these are at present recognised as possibly workable, but only one, near the top of the series, is worked. It varies from 12 to five feet thick and occupies a position about 120 to 150 feet below the base of the Moturs. The intervening strata consist of sandstones and shales. Leaf impressions of typical Damuda fossil plants are often met with, but are not common everywhere. The lower seams occur within 100 feet below the main seam and are underlaid by gritty sandstone and black shales which in turn overlie the Talchirs. The full thickness of the Barakars has not been proved, but is estimated at from 350 to 400 feet. These rocks can be seen in between Barkuhi and Parasia and southward to Khirsadoh.

Talchirs or the basal series of the Gondwana system are well exposed about Khirsadoh. The boulder bed is seen in the nala near the village on the line of a strong fault, and the curious greenish clays of this series are exposed south of the railway station. Better and more extensive outcrops of these interesting rocks can be studied in stream sections, a mile or so south-west of Jamai (Junnor Deo railway station) in the Kanhan area. The field evidence in that area suggests that the Barakars are conformably superposed on the Talchirs. No fossils have been found in typical Talchir rocks in this tract. The thickness of the beds is difficuit to fix, owing to the irregular surface of the old rocks on which they rest unconformably.

Archæan granites. A large area of granites lies between Chhindwara town and the edge of the Pench Valley coalfield near Khirsadoh railway station. These rocks are coarse porphyritic granites and known to be intrusive in the still older gneisses, which are also seen near Khirsadoh and eastwards to beyond the Pench river. They are nevertheless very old and considered as of Archæan age.

Archæan gneisses and schists. These are, of course, the oldest rocks of the area, but even these, which consist of gneisses, schists, hornblendic rocks and other types between Khirsadoh and the Pench, can be subdivided.

The most important feature in the structure of the Pench Valley coalfield is a strong line of faulting along the margin of the Archæan rocks, so that the Gondwana strata are brought in to the north. These beds have gentle northward dips so that each series—Talchirs, Barakars, and Moturs—succeed each other northward. A long period of erosion followed this faulting and tilting, and then on the upturned beds thus laid bare the Deccan basalt lavas were poured out. The dykes of dolerite in the Gondwanas represent the channels of extrusion of the lava. Subsequently, further faulting along lines roughly parallel to the main boundary fault took place, and these dislocations have sliced the Gondwanas into strips, usually step-faulted, with downthrows to the south and sometimes to the north.

Gajandoh Area.

A small area of Barakars and Moturs appears from beneath the Infra-trappeans and basaltic traps of the Bhandaria forest in the Thaonri nala, a mile north of Gajandoh village (22° 9′ : 78° 44′). The area was re-mapped by Mr. E. R. Gee in 1924, but at the time of his visit the coål outcrop was obscured. Mr. E. J. Jones (1884-86), however, records a five-foot seam under eight feet of shale. The beds are against the main south boundary fault and dip gently northward under trap, and are the southward limit of the Barakars of Barkuhi and Chandameta. Exploration in this area will mean boring through the trap to prove the continuation of the beds

and finally working will have to be under the cover of the rocks which overlie the coal including the basaltic lavas of Bhandaria forest.

Barkuhi Area.

Coal was already being extracted at Barkuhi (22° 11′ : 78° 42′) at the time of Dr. Blanford's visit here in 1866, and it is still one of the collieries of the present company. Several borings have been put down in the area to prove the extension of the nine-foot (8 feet 6 inches) seam of coal under the Barren measures across the faults which traverse the tract. In the time of Captain Leslie Ditmas (1905) it was already known that in the adjacent area at Chandameta a small seam was present above the nine-foot seam, and two seams below it. It was then thought that the lower seams were of better quality. Under the Moturs near Barkuhi it has been found that the so-called nine-foot or Barkuhi seam occurs about 120 feet below the base of the red rocks, so that it would seem evident that this seam is the same as the Datla and Ghorawari main seam and the lower seams are in their correct position, although with thicker strata between. The true thickness of the Barkuhi seam may be taken as from 7 feet 6 inches to a little under six feet. There is said to be a four-foot seam above it, but this is not normally worked.

Mr. Hobson took a full seam sample over a height of 5 feet 4 inches in Barkuhi (Barkui) No. 2 and 1 foot 3 inches roof coal and 4 feet 8 inches floor coal in No. 3. His analyses are as follows:—

	No. 2.	No. 3.
	Per cent.	Per cent.
Moisture	7·38	1·68
Volatile matter	29·98	21·98
Fixed carbon	44·52	51·62
Ash	18·12	24·72
Calorific value	5,649 calories.	6,224 calories.
Caking quality	Slight	*Nil.*

The coal in No. 1 Barkuhi has been almost completely extracted. Work was in progress for extracting from No. 2 at the time of Mr. Hobson's visit (1924), and development was being made to prepare No. 3 for working at the same time. All these areas are south of the Ambara fault, which crosses towards the west of Chandameta Hill, from north of Barkuhi railway station.

Bhandaria-Bhutaria Area.

Half a mile south of Barkuhi there is a strong east-west fault with a south downthrow, which brings in the trap of the Bhandaria forest. This fault is traceable from south of Ambara to Harrai where it is still important. North of the fault, all along the Barkuhi branch of the railway, coal measures occur under Bhutaria (22° 11′ : 78° 44′) and Bhandaria (22° 11′ : 78° 45′) to the south of Parasia. As the fault brings in the trap to the south, these Barakars belong to the Barkuhi and Chandameta area. The presence of coal in this area was known in the time (1866) of Dr. Blanford, who named the seams met with after the three villages mentioned. At the Bhandaria exposure in the *nala* (Gogra), about a mile south-west of Parasia, he noted 7 feet 3 inches of coal in four seams in 15 feet 2 inches of strata. The Bhutaria outcrop occurs further west, almost on the boundary of the Barkuhi property.

In the area under consideration, but about a mile south-east of Barkuhi railway station, a colliery has been opened known as East Barkui. The seam here worked shows 2 feet 6 inches of top coal and 5 feet 6 inches of bottom coal with a six-inch shale parting between. Usually only the floor coal is worked. Mr. Hobson took a sample over 5 feet 7 inches of the seam, and gives the following analysis of the coal :—

	Per cent.
Moisture	1·70
Volatile matter	15·83
Fixed carbon	55·94
Ash	26·53
Calorific value	5,980 calories.
Caking quality	*Nil.*

There is little doubt that this is rather an exceptional analysis, as the low percentage of the volatile matter is suggestive of the effect of a dolerite dyke. Such intrusions are known both here and at Barkuhi[1]; and such dykes are well seen, south and east of Chandameta and appear to be connected with the trap outlier, just north of Bhutaria.

Chandameta-Dongar Chikhli Area.

This tract extends eastward from Barkuhi almost to the Tamia motor road. Chandameta (22° 11′ 30″ : 78° 44′) is situated on

[1] *Rec. Geol. Surv. Ind.*, XLIV, p. 123, (1914).

Barakars, while Dongar Chikhli (22° 12′ : 78° 45′) is on the trap of Chandameta Hill and lies north of the valley in which the pits of this section have been put down. Various records have been given for the thickness of the coal seams in this area, but a bore-hole at Wallace pit (Chandameta) shows two feet coal, 4 feet 6 inches blue shale and 9 feet 6 inches coal at a depth of 80 feet (to the top seam). And there are three smaller seams below, all within a depth of 155 feet from the surface. Mr. Hobson cut a sample from the full seam being worked in No. 2 incline and records six feet of coal. His analysis of this is:—

	Per cent.
Moisture	7·48
Volatile matter	31·24
Fixed carbon	44·24
Ash	17·04
Calorific value	5,688 calories.
Caking quality	*Nil.*

The area is crossed by two faults, the dips are northward, and the Barren Measures come in that direction.

Two borings in the Dongar Chikhli area only proved the upper seams, *i.e.*, one foot coal, six feet blue shale and six to seven feet coal at depths of 116 to 130 feet. This area is also crossed by two faults. The area lies immediately east of that of Chandameta and is followed further east by that of Parasia. The Moturs lie between the Barakar outcrops, south of the G. I. P. Railway, and the traps on which the village of Dongar Chikhli stands. Mr. Hobson sampled the seam, 5 feet 7 inches, and gives the following analysis of the coal:—

	Per cent.
Moisture	9·60
Volatile matter	28·94
Fixed carbon	44·28
Ash	17·18
Calorific value	5,544 calories.
Caking quality	*Nil.*

From the evidence of the borings it is clear that both at Chandameta and here we are dealing with the same series of coals as in the Kanhan area, although the thin shale parting near the top makes the main seam appear a little different. The non-caking character of the seam is easily accounted for by the larger moisture

content. In fact, it may be anticipated that, at greater depths, the moisture will be found less and the caking quality improve. It is also evident that there must be a fault between the Dongar Chikhli-Chandameta area and the Bhandaria-Bhutaria area to the south, by which the beds are thrown down to the south.

Reserves of coal.

The total area involved in the Barkuhi, Chandameta, and Dongar Chikhli areas is roughly two square miles, and this with a 5-foot 6-inch seam of coal will mean 11,000,000 tons of coal, without deductions for coal extracted, spoilt by dykes and faults and left in the mines. But it may be taken that 5,000,000 tons are still available. If we include the southern strip of Bhutaria to Bhandaria, perhaps another half million tons might be included; whereas for the larger tract to the south, under the Deccan trap of Bhandaria forest to Gajandoh, where about three square miles of concealed coal measures occur, the additional amount would be of the order of 10,000,000 tons.

Eklaira-Newton Chikhli Area.

North of the Ambara-Barkuhi fault and up to the fault south of Eklaira to Bampri (Bamori), there is an area of about a square mile, mostly covered by Moturs under which coal must occur within 250 feet. The reserves here will be of the order of 5,000,000 tons, of which 3,000,000 should be obtainable. This tract is included in the section now to be dealt with. North of this Eklaira fault there are five concessions—Eklaira, Bhajipani, Jatachhapar, Bamori and Newton Chikhli—the last is not one of Messrs. Shaw Wallace's areas. Jatachhapar lies to the dip of Bamori and is largely covered by Moturs; the others are on the strike of an outcrop of Barakars. The dips are northward, and east-west faults of relatively small throw cross the concessions. Several borings have been put down through the Moturs to the dip of the workings of Eklaira, Bhajipani, and Bamori, and in Jatachhapar. In all these the coal measures have been found at depths within 300 feet.

The records thus obtained cover an area of nearly two square miles about Eklaira (22° 12′ 30″ : 78° 41′ 45″), Bhajipani (22° 11′ 30″ : 78° 42′ 30″), Bamori (22° 11′ 30″ : 78° 43′) and Jatachhapar (22° 13′ : 78° 43′), and thus mean fully 10,000,000 tons of coal in the main seam. Allowing for losses, etc., a total of 7,000,000 tons should be available. But there is little doubt that there are coal measures

within workable depths far out under the Pench river. And, if any strong faults with an upthrow to the north occur, the coal measures may be found further on north of Likhawari (22° 14′ : 78° 44′); but there is no proof of this yet, as no deep borings appear to have been put down so far to the north. Further there are trap intrusions between Belgaon and Likhawari.

Mr. Hobson took samples in the workings of the collieries in the Eklaira area. His sample here, from 1 foot 3 inches roof coal and 4 feet 9 inches floor coal, gave :—

	Per cent.
Moisture	6·98
Volatile matter	28·47
Fixed carbon	45·14
Ash	19·41
Calorific value	5,668 calories.
Caking quality	Slight.

At the Bhajipani workings Mr. Hobson took a sample from 1 foot 9 inches roof coal and 5 feet 1 inch floor coal and obtained by analysis :—

	Per cent.
Moisture	7·54
Volatile matter	28·82
Fixed carbon	44·96
Ash	18·68
Calorific value	5,894 calories.
Caking quality	*Nil.*

In the Bamori colliery Mr. Hobson took a sample from the worked section of the seam (5 feet 2 inches, *i.e.*, only floor coal), and his analysis shows :—

	Per cent.
Moisture	8·34
Volatile matter	30·02
Fixed carbon	45·60
Ash	16·04
Calorific value	5,697 calories.
Caking quality	*Nil* to slight.

Newton Chikhli colliery is situated on the north side of the Great Indian Peninsula Railway, at the north-west corner of Chandameta Hill. In addition to the inclines on the outcrop of the main seam, a boring (and now a pit) has proved the seam to the dip (north-east) at 120 feet. The area is troubled by parallel faults

of small throw trending E. N. E. The roof coal in the workings is 2 feet 10 inches thick and the floor coal 5 feet 9 inches, with an eight-inch parting between them. Mr. Hobson found the average analysis of the two coals to be:—

	Per cent.
Moisture	7·69
Volatile matter	29·99
Fixed carbon	42·12
Ash	20·20
Calorific value	5,468 calories.
Caking quality	*Nil.*

There is little doubt that the coal continues to the dip under the Moturs.

Parasia-Khirsadoh Area.

The name Parasia is taken from the village of Dongar Parasia (22° 12′ : 78° 46′) and the other from the station of Khirsadoh (22° 10′ 30″ : 78° 46′ 30″) on the Bengal-Nagpur Railway. Khirsadoh village lies a mile to the east of the station. There are really two sections of Barakar outcrops, with a thin cover in places of Moturs and a few outliers of trap with trap dykes, separated by the Bhandaria-Harrai fault. There are other faults in each of the two sections. The Parasia area lies east of the Tamia road, between the concessions of Dongar Chikhli and Rawanwara. The Khirsadoh area to the south lies east of the trap area of the Bhandaria forest, with the Harrai tract to the east of it. There is now no mining in progress in either the Parasia or Khirsadoh sections, but several old workings are to be seen.

North of Parasia railway station, a boring just east of the Tamia road, proved three seams of coal beyond the now abandoned Craddock Colliery—a six-foot seam at 72 feet, a four-foot seam at 102 feet, and a 4½-foot seam at 133 feet. The top seam is evidently the main seam of the Pench Valley field, although the distinguishing little roof coal is not mentioned. The area is an interesting one, as the Barakars must continue under the Moturs and traps to the north, but the faults and dyke near Parasia make it appear more complicated to the north than perhaps it really is. The Bhandaria-Harrai fault has a downthrow to the south and crosses east-

ward almost at the fork of the Bengal-Nagpur Railway to Barkuhi, and the switch line to Parasia.

Although several old workings exist in the Khirsadoh area, they indicate exploratory efforts. The area is sliced by faults and cut by at least one dolerite dyke, and the interesting point about is, that it shows that the Barakars must extend westward under the trap of the Bhandaria forest. A boring was put down near the shaft (Mahadeo pit), just west of the Kapodoh (Gogra) *nala*, west of mile 67 on the Tamia road, to a depth of 388 feet without going through the Barakars. This boring (22° 11′ : 78° 46′) was begun at the edge of the trap and on the margin of the Moturs; a record of it, made during May and June 1909 under the care of Mr. W. Berry, was very kindly supplied by Abdul Ali, Hasan Ali Bros. It is given below :—

Strata met with.	Thickness.		Depth.	
	Feet.	Inches.	Feet.	Inches.
Surface soil	12	0	..	
Murum and trap nodules	24	0	12	0
Red and grey clays	40	0	36	0
Hard black clays	64	0	76	0
White sandstones	3	0	140	0
Micaceous sandstones	2	0	143	0
Shaly sandstones	45	0	145	0
Coaly shale	1	0	190	0
Shale	2	0	191	0
Shaly sandstone	5	9	193	0
Coarse sandstones	4	3	198	9
Good coal	3	0	203	0
Shale	0	6	206	0
Good coal	4	0	206	6
Shale	0	6	210	6
Coal	1	0	211	0

Strata met with.	Thickness.		Depth.	
	Feet.	Inches.	Feet.	Inches.
Shale	6	0	212	0
Shaly sandstone	11	6	218	0
Good coal	4	6	229	6
Shaly sandstone	6	0	234	0
Shale	4	0	240	0
Coal	3	6	244	0
Shale parting	0	9	247	6
Good coal	4	0	248	3
Shaly sandstone	3	3	252	3
Shaly sandstone	4	6	255	6
Shale	1	0	260	0
Good coal	3	6	261	0
Shale	1	6	264	6
White sandstones	85	0	266	0
Shaly sandstone	9	0	351	0
Shale	15	0	360	0
Coal	4	0	375	0
Shale	1	0	379	0
Fine, hard sandstone	8	0	380	0
	to base		388	0

There are thus eight seams of coal, but 1, 2 and 3 probably represent the main seam of the Pench valley, 4 is the second below it, 5 and 6 can be considered as the third seam from the top, and 7 is the fourth, while 8 is the basal seam of the series, unless others occur below. This is the most complete section found, so far and it is unfortunate that the boring was not carried down to the Talchirs, which can hardly be 100 feet lower. Judging by the exposures south of Jamkunda and north of the Dhow forest, I think

the basal seam above must be really the lowest seam of the series in this area. The shaft of Mahadeo pit was sunk to the bottom seam above mentioned, but was full of water at the time of my visit in 1924.

Rawanwara-Harrai Area.

Here again two sections are involved, one east of Dongar Parasia with its continuation, and the other separated by the Harrai-Bhandaria fault to the south of Rawanwara, and the eastern continuation of the Khirsadoh section. The Harrai tract was visited by Dr. Blanford in 1866, and inclines have been put in to a seam which outcrops near the village (on trap with Infra-trappeans below). These workings are, however, north of the fault and really in the Rawanwara area, although within the mouza of Harrai. Coal is found south of the fault, in a well recently made, north-east of the village. The Harrai tract may be dismissed as a prospective coalfield until more data is available, when it is likely that the area under the trap east of the *nala* will prove more attractive.

As regards the Rawanwara area, there are one or two important faults south of, and a dolerite dyke north of the village, which is on Barakar sandstones. The Harrai Colliery (abandoned) lies to the south down the Seemkole *nala*. There is a small area of Motur red clays to the south-east of the village. The strata strike westwards to Parasia and dip north under the trap of the Rawanwara forest. Rawanwara colliery is situated west of the village, but has been closed down since a collapse in the main workings. However, a fresh mine has been opened to the east of the old one, and a thin seam of 2 feet 4 inches was worked at the time of Mr. Hobson's visit in 1924. His sample from this mine and seam yielded :—

	Per cent.
Moisture	5·55
Volatile matter	29·84
Fixed carbon	49·35
Ash	15·26
Calorific value	6,286 calories.
Caking quality	Slight to *nil*.

As there are several boring records showing the presence of the main Pench Valley seam in this vicinity at relatively shallow depths, it should not be difficult to say whether the 2 feet 4 inches seam above is the roof coal of the main seam or another seam. However,

a pit ten feet deep from the floor of the seam would settle the question as to the main seam.

To the north-east of Rawanwara village, an incline has driven across a dolerite dyke into the measures to the north, and struck a seam said to be seven feet thick. It is presumed to be the main seam, but, as the incline was flooded, it was not possible to ascertain this and only a basketful of coal was secured for analysis by Mr. Hobson. His results are :—

	Per cent.
Moisture	2·33
Volatile matter	8·31
Fixed carbon	73·25
Ash	16·11

The low volatile percentage is clearly due to the heating effects of the intrusion. The analysis suggests a good quality coal, but it is to be remembered it is not a sample. Again the Barakars must extend northward under the Deccan trap hills of the Rawanwara forest, and should lie within workable depths for some distance from their outcrops near Rawanwara.

Dighawani-Chhinda Area.

The Rawanwara outcrop of Barakars continues into Dighawani and across the Pench river to Setia, a mile north of Chhinda (22° 12′ : 78° 51′). The same conditions are present, except that a strong fault, throwing southward, crosses east-north-east from the Harrai fault to just south of Setia. The red clays of the Moturs are in evidence south of the fault, south of Dighawani (22° 12′ 30″: 78° 49′), where they are overlaid by infra-trappean grits and these capped by Deccan trap lavas. The Rawanwara dolerite dyke is seen in the Pench river north of the fault, and the main mass of the lavas of Rawanwara forest occur in the river a little further upstream. The Barakars are exposed between the fault and the trap hills to the north.

A boring near Dighawani proved the main seam 7 feet 6 inches at a depth of nine feet, in the bed of the stream that flows east to the Pench, south of the village. Dr. Blanford [1] has discussed the coal outcrop in the Pench river where the dyke is seen; he found the section to show three seams in 15 feet 6 inches of strata

[1] *Rec. Geol. Surv. Ind.*, XV, p. 127, (1882).

with a total of 12 feet 3 inches of coal. Although this place is not suitable for opening a mine, there is little doubt that the area north of the dyke and under the trap may be worth examination by boring. Dr. Blanford gives an analysis of the coal and shows, on a moisture-free basis, volatile matter 16 per cent., fixed carbon 61 per cent., and ash 23 per cent. The effect of the dyke is evident in the low percentage of volatile matter. The same seam has been proved by boring at a depth of 35 feet in the valley south of Setia (22° 13′ : 78° 51′), north of the fault.

As regards the area south of the Pench or Setia-Harrai fault, the alluvium obscures the area; but the Barren Measures are present, so that the coal will be at some depth greater than 150 feet, and possibly within 250 feet, of the surface. There is, however, a show of Barakar sandstones half a mile north-east of Kukarmunda (22° 12′ : 78° 52′), as an inlier among the Deccan trap lavas, which occur between Chhinda and Sirgora. Some exploration has been made here, but a boring is required at the north edge of this exposure. Some care is necessary in fixing a bore-hole site as it is almost certain that the Bhandaria-Harrai fault (throwing south) passes here from the south margin of the Sirgora area. Here again it will mean that the main coal seam will have to be worked under trap hills north of Kunkarmunda.

Sirgora-Haranbhata Area.

This area first explored by Major Ashburner and shortly after in 1866 examined and favourably considered by Dr. Blanford has been since tested. The results were so satisfactory that the branch line from Khirsadoh was under construction in 1905. The Barakars are well seen in the *nala* east of Sirgora (22° 12′ 30″ : 78° 53′) and in the Mandlajoh, which flows south to the west of Haranbhata (22° 12′ : 78° 55′); there is one large central outlier of Deccan trap and two smaller ones near Sirgora. The Moturs are absent, but a thick bed of Infra-trappean conglomerates (with red jasper) lies between the Barakars and the overlying trap. A strong fault, throwing southward, trends west from south of Haranbhata and is thought to continue into the Bhandaria-Harrai fault; to the south of this fault the traps are brought in. There is also a fault, cutting off the Barakars along the north, which trends

westward, as though to pass just north of Chhinda, and evidently throws the beds down northward.

Several borings have been put down in this field, chiefly around Sirgora, and coal has been found in each, at depths not exceeding 60 feet. It is clear that at least two seams have been proved, and that one of them is the main seam of the Pench Valley field. Analyses of coal samples obtained from the Sirgora area are given in the Geological Survey of India Laboratory Book, Volume IV, page 45, for 1897. No borings appear to have been put down in the Mandlajob valley, but it is almost certain that the same seams will occur here. There are no grounds from the available evidence to show that, in this vicinity, we are approaching the edge of the basin in which the coal measures were laid down, except that in the valley of the Gunnor river about Thesagora (22° 13′ : 78° 58′), four miles E. N. E. of Haranbhata, there is an inlier of gneisses. These rocks may merely indicate an irregularity in the floor of the basin. The Barakars appear to be in full force here. A boring in the valley of the Mandlajob would be valuable in proving this point.

Pench Valley about Paijanwara.

Before closing these remarks on the Pench Valley coalfield, a word is necessary in regard to the area east of the Tamia road, from Belgaon (22° 14′ : 78° 45′) to the Ghatmali river, east of Paijanwara (22° 14′ 30″ : 78° 49′). In this extensive area the strata are considered as Moturs and there are several dolerite dykes and sills, and evidence of parallel faults similar to those met with in the Barkuhi and Eklaira areas. As most of these faults appear to have their downthrow to the south, it may well be that the coal measures below are not at very great depths on the upthrow side of such faults. There are places, as near Titra (22° 16′ : 78° 50′), up the Ghatmali, where black shales appear. So far as we know such shales are rare in the Barren Measures.

There can be no question that the coal measures of Mohpani are part of the same series as those of the Pench. And it is as certain that these coal measures extend from one area to the other under the newer rocks which cover the intervening country. The coal measures must, however, lie at great depths under these younger formations. There is also no doubt that the coal measures are

continuous westwards to the Tawa coalfields of Shahpur in Betul. If the whole of these Barakar strata have a westward tilt it must follow that they should emerge to the east towards the Seoni country. As this tilt is likely to have taken place before the cover of Deccan lavas was poured over the country the conclusion is that the Barakars of the eastern region were removed by the erosion which obviously took place in pre-Deccan trap times. Thus it is probable that no coal measures may be expected under the traps of Seoni. As stated none are seen in the Gunnor river, and for practical pur poses the eastern limits of the coal measures may be taken as this longitude.

Production of Coal from Pench Valley.

The annual output of coal from the Pench Valley fields, and latterly also from the Kanhan field of Ghorawari, are given below :—

Year.	Tons.	Year.	Tons.
1901	..	1918	267,303
1902	..	1919	285,356
1903	88	1920	279,483
1904	*Nil.*	1921	449,311
1905	1,104	1922	453,484
1906	32,102	1923	346,094
1907	74,663	1924	473,896
1908	120,249	1925	485,768
1909	92,196	1926	416,708
1910	87,677	1927	505,913
1911	63,030	1928	556,481
1912	90,722	1929	680,270
1913	89,959	1930	740,391
1914	95,679	1931	750,015
1915	103,152	1932	831,817
1916	154,548	1933	978,179
1917	204,502		

NAGPUR COAL.

South of the coalfields that trend from Shahpur in the Betul district to the Pench valley in Chhindwara, there is a belt of gneisses and granitoid rocks, which Dr. L. L. Fermor has referred to as the Satpura protaxis. South of this belt, the gneisses are covered by the Deccan trap lavas as far as the scarp of the Satpura uplands, facing Nagpur. In the plains below gneisses again appear, but near Nagpur Talchirs and Kamthi sandstones are seen on the older rocks and below the Deccan trap. It was thought that the sandstones might belong to the coal measures (Barakars) and that coal might be expected in this area.

The subject was investigated by Dr. W. T. Blanford[1] who gave it as his opinion that the coal measures were not present and that the matter could be definitely decided by borings 200 to 250 feet deep in the vicinity of the following places:—Bokhara (Buckaira; 21° 27′ ; 79° 10′); Silewara (Seelaiwara; 21° 17′ : 79° 7′); Bhuruthwara (21° 14′ : 79° 1′); Sonair (Saoner; 21° 22′ : 78° 55′); Kailod (Kelod; 21° 27′ : 78° 52′); Agra near Chorkyree (Chorkhairi; 21° 32′ : 78° 59′); Shahpur (?) and Bazargaon (21° 8′ : 78° 46′).

Subsequently, Dr. Blanford's opinion of the age of these Kamthi (21° 15′ : 79° 11′) sandstones was confirmed by the discovery of fossil plants near Silewara and Bazargaon. These showed the strata to be the equivalent of the Raniganj series of Bengal and of the Bijori beds of the Satpura coalfields, where no workable seams have been found. The occurrence of coal is, of course, possible; but, as the borings carried out at Bazargaon[2] evidently did not prove any coal, it is idle to speculate further.

CHIKALDA COAL.

Chikalda (21° 23′ : 77° 20′) is situated on the Gawilgarh hills which overlook the plains of the Purna valley in Berar. In the Indian Museum, Calcutta, is a piece of coal picked up (below a house) in one of the ravines at Chikalda many years ago; an analysis, dated 1861, shows this specimen to have (dry basis) 33·2 per cent. volatile matter, 62·5 per cent. fixed carbon, and 4·3 per cent. ash. It is of the Gondwana type but of such excellent quality as to suggest a piece of vitrain from a carbonised fossil tree stem. The

[1] *Rec. Geol. Surv. Ind.*, I, p. 26, (1868).
[2] *Op. cit.*, XXXIX, p. 57, (1910).

rocks of the Gawailgarh scarp are Deccan trap lavas; But there is a well-known fault along the foot of the scarp along which, on the north (upthrow) side, certain sandstones do show up under the lavas and infra-trappean beds, 18 miles to the east of Chikalda.

The line of this fault and of the outcrops of this sandstone, thought to be the same as these near Nagpur, *i.e.*, of Kamthi age, have been discussed by Dr. Blanford.[1] No coal and no tree stems nor other plant fossils have been found in these sandstones at any of the exposures known—Bairam Ghat (21° 23′ : 77° 37′), Balkhera (21° 23′ : 77° 45′), Salbardi (21° 25′ : 78° 1′), or further east. Mr. E. R. Gee, in 1924-25, specially examined the Bairam Ghat outcrop eight miles from Ellichpur (21° 16′ : 77° 31′), on the road to Betul, and came to the conclusion that without fossil evidence it was not possible to give a precise age to the sandstones. He found no coal and records no evidence of fossil wood in any form. So it may be that the coal from the Chikalda glen came from the house above and is foreign to this area.

[1] *Mem. Geol. Surv. Ind.*, VI, pp. 278-283, (1867, reprint 1921).

CHAPTER 16.

COALFIELDS OF THE CENTRAL PROVINCES—*concld.*

WARDHA VALLEY COALFIELDS OF CHANDA.

General.

The occurrences of the Barakar series of coal measures now to be considered lie in the drainage area of the Wardha river and its tributaries from the east, including the Wainganga river. From the confluence of these two large rivers to their junction with the Godavari, the united stream is known as the Pranhita. The coal-bearing areas of the Pranhita and Godavari river will be treated in the next chapter. The country intervening between the exposures of Kamthi sandstones, west of Nagpur and near Ellichpur, mentioned in the previous chapter, and the vicinity of Warora (20° 13′ : 79°) in the Wardha valley, is covered by the basaltic lavas of the Deccan trap. The question of finding coal under the trap in the vicinity of the Great Indian Peninsula Railway about Pulgaon (20° 44′ : 78° 19′) has been discussed on more than one occasion. It is pure speculation on a possibility which can only be proved by boring—preferably near Sirpur (20° 32′ : 78° 23′) or Pohna (20° 21′ : 78° 45′) lower down the Wardha river. Rocks older than the Deccan trap show up at the confluence of the Wanna near Savangi (20° 18′ : 78° 48′), while the first exposure of Barakars in the Wardha valley is that in the Dehwal *nala* north-west of Aikona (Yekona; 20° 15′ : 78° 56′). The boring made at Zagra near Aikona proved seven feet of coal at 50 feet without going to the base of the seam.

The discovery of coal was first recorded in *Gleanings of Science*, III, pages 281-283, (1831), and possibly refers to the coal in the banks of the Wardha river near Kumbhari (19° 57′ : 79° 6′). The areas immediately north of Warora about Pisdura (20° 21′ : 79° 3′), Dhamni (20° 15′ : 79° 8′), Dongargaon Hill (20° 12′ : 79° 4′) and Mangli (20° 22′ : 79°) have been made famous by Mr. S. Hislop's[1] finds of

[1] *Q. J. G. S.*, X, p. 470, (1854); *Pal. Ind.*, New Ser., III, No. 3, (1908).

fossils—bones of a large Dinosaur, of a fish, and of the plastron c a fresh-water turtle, and other animal remains and shells—in bed regarded as Infra-trappean and of Upper Cretaceous age. The Mang beds yielded the cranium of a labyrinthodont reptile (*Brachyop laticeps*) which indicates a Triassic age and these strata are consi dered as the equivalents of the Panchets of Bengal.[1] In the las paper Dr. C. A. Matley has suggested that the beds about Dongar gaon Hill are Inter-trappean and therefore a little younger tha those of Pisdura.

Dr. W. T. Blanford[2] paid a short visit to the Chanda distric at the invitation of Captain Lucie-Smith, then (1867) Deput Commissioner of the area, and a year later Dr. T. Oldham[3] gav some details of the search for coal. In 1870 the first collier was opened at Ghugus (19° 56′ : 79° 7′) by the Viceroy, Lord Mayo In 1875 Mr. F. Fedden discovered the glacial pavement on the south bank of the Penganga river, near the village of Irai.[4] The detailed geological survey of the Wardha Valley coalfields wa made by Mr. T. W. H. Hughes[5] during 1870-76.

The Wardha Valley coalfields have not been resurveyed since Mr. Hughes mapped the district over 50 years ago. Much development work has been done in the intervening years. About 1873 an important colliery was established at Warora after it had been decided to abandon the mine at Ghugus, and as a result of borings at Warora[6] which had proved two valuable seams. In 1906, after a serious subsidence at Warora, this colliery also was abandoned. This action had been anticipated, and coal having been proved in 1900 by boring at Ballarpur (Ballalpur; 19° 51′ : 79° 21′) and shafts sunk there in 1903, operations were transferred to this locality. The Ballarpur collieries are now being energetically worked by a private firm, largely due to the enterprise of Sir Maneckji B. Dadabhoy. As early as 1870 coal had been suspected at Ballalpur, and at the same time had been discovered across the Wardha river at Sasti (19° 49′ : 79° 20′), in the Adilabad *taluq* of Hyderabad State.

[1] *Mem. Geol. Surv. Ind.*, LVIII, p. 157, (1931); *see* also *Rec. Geol. Surv. Ind.*, LIII, pp. 159-162, (1921).
[2] *Rec. Geol. Surv. Ind.*, I, p. 23, (1868).
[3] *Op. cit.*, II, p. 94, (1869).
[4] Warai, 19° 53′ : 79° 9′. *See Rec. Geol. Surv. Ind.*, VIII, p. 16, (1875).
[5] *Mem. Geol Surv. Ind.*, XIII, (1877, reprinted 1933).
[6] Chanda District Gazetteer, p. 278, (1909).

In addition to the collieries now working at Ballalpur and Sasti, the Ghugus area has been worked by the same company, who have also opened a new colliery at Rajur (20° 7′ : 78° 54′), to which the railway has been extended across the Wardha river *viâ* Wun, from Majri (20° 8′ : 79°) on the Wardha-Chanda-Balharshah line. This line from Balharshah (station for Ballalpur) has now also been continued southward into the Nizam's Dominions to Kazipet on the Hyderabad-Bezwada line. Coal has been worked in a small way near Chanda town at Mahakali, Babu Pet and Lalpet; and borings have proved coal at various other places—Majri and Telwasa (20° 3′ : 79° 5′)—though of course not at Bhandak (20° 6′ : 79° 7′). Finally, there is an isolated area of Lower Gondwana (Talchir, Barakar and Kamthi) near Bandar (20° 30′ : 79° 17′), north-west of Chimur (20° 29′ : 79° 21′), where three seams of a total thickness of 38 feet of coal have been proved by boring in a tract of roughly five square miles.

Geology.

Both from an economic and from a geological point of view, few districts in the Central Provinces are of a greater interest than Chanda. The following geological formations have been recognised within its borders:—

Recent to Pleistocene . .	River alluvium, older gravels, bone beds, and laterite.
Cretaceous	Deccan basalts, Inter- and Infra-trappean (Lametas) beds.
Jurassic	Chikiala beds with coal. Kota fish and plant beds.
Triassic	Maleri reptilian beds. Mangli *Brachyops* beds.
Permian	Kamthi (Raniganj) beds. Barakar coal measures.
Upper Carboniferous . .	Talchir (glacial) series.
Cambrian to Pre-Cambrian .	Sullavai sandstone series.
Purana	Pakhal shale and limestone (Pengango) series. Granitic rocks of north east.
Archaean	Dharwars of Bhandara. Gneisses and schists in Wainganga river.

The study of a geological map of the Chanda district shows that (Sullavai ? Cambrian) sandstones, seen north-west of Mul (20° 4′ : 79° 41′), overlapped the Pakhal (Pre-Cambrian) limestones and

shales of the Penganga river on to the basement Archæan gneisses. There is then a vast interval between the unfossiliferous, supposed Cambrian, strata and the ice age of Talchir times. When the Lower Gondwana sediments were being laid down, a rift valley, due to trough faulting along a north-west strike, appears to have begun and evidently continued as the sediments were deposited in it. Nevertheless, the Bandar coalfield shows that the sediments were not strictly restricted to the main rift valley. Desert conditions are thought to have existed at the time the Mangli labyrinthodont *Brachyops* existed; and this arid climate persisted throughout most of the Triassic period until the Maleri crocodilian *Parasuchus* appeared. Maleri (19° 11′ : 79° 36′) is outside the Chanda district in Hyderabad State, about ten miles eastward of Tandur (19° 9′ : 79° 27′), just beyond Bitrapalli. The ganoid Liassic fish remains and cycadaceous plant remains in the succeeding Kota (18° 54′ : 79° 58′) beds indicate milder conditions; and the coal and fluviatile character of the Chikiala (19° 4′ : 79° 56′) beds confirm the continuation of this amelioration of climate through the Jurassic period.

Dr. C. A. Matley[1] in his paper 'Recent discoveries of Dinosaurs in India' has very ably argued that the highest beds of the Lower Gondwanas are not much older than the Infra-trappean (Lametas) beds of Pisdura. He had previously suggested that the fossils found near Dongargaon came from an Inter-trappean horizon. However, we are still of the opinion that, in the Chanda area at least, there is a hiatus between the Chikiala beds and the Lametas of Pisdura. In fact, we go so far as to suggest that faulting along the lines already mentioned continued after the Chikiala beds were laid down and before the Infra-trappeans of Pisdura were deposited. These movements evidently heralded the Deccan trap eruptions; but before the outpouring of the lavas a considerable amount of denudation had taken place. It is to these Pre-trappean movements along old fault lines that we owe the preservation of the Barakar coal measures within the old rift valley and their restriction to this belt of country to-day. This is why we suggest that the search for coal under the Deccan lavas will be more successfully made along the north-west continuation of the rift valley floor.

[1] *Geol. Mag.*, LXVIII, pp. 274-282 (1931).

For purposes of descriptions, it is simplest to consider separately the areas in which the Barakar coal measures actually appear at the surface, and, when discussing these, to indicate extensions of the coal seams below newer rocks. From this point of view the Wardha Valley coalfields may be considered under the following sections:—(1) the Bandar coalfield; (2) the Warora area; (3) the Rajur coalfield; (4) the Telwasa area; (5) the Ghugus coalfield; (6) the Chanda town area; (7) the Ballalpur coalfield; (8) the Lathi area; and (9) the coal prospects at Kota. In the case of Ballalpur, it is to be understood that the main outcrops of the Barakars are at Sasti; and this is also true of Lathi (19° 34′ : 79° 30′), where the outcrops are near Antargaon (19° 33′ : 79° 29′). Lastly, in the extreme south of the Chanda district, the prospects at Kota are based on the outcrops just west of Chinur (18° 52′ : 79° 48′). All three of these outcrops are west of the Wardha and Pranhita river in the Nizam's Dominions. The actual outcrops will therefore be considered in the next chapter under their correct localities.

Outcrops of Barakar rocks.

Bandar Coalfield.

This field was discovered by Mr. T. W. H. Hughes[1] about 1872 by the presence of Lower Gondwana rocks, although no coal was actually seen. The area involved lies about six miles north-west of Chimur (20° 29′ : 79° 21′), and the Barakar and Kamthi rocks rest on Talchirs. The Talchirs are seen along the margin, to the east and west of the triangular area of the Damuda rocks, which comes to a point in the south. The base of the triangle is to the north, where the Damudas disappear under Lametas and their cover of the Deccan trap lavas. These Damuda rocks occupy an area of 12 square miles, but this is largely composed of Kamthi beds which are not conformable to the Barakars. Mr. Hughes had said that the existence of coal might be proved by boring, and his suggestion was carried out, and three seams of coal proved. He named the field after the little village of Bandar (20° 30′ : 79° 18′) where Barakars occur, although the borings seem to have been put down near Morepar (20° 33′ : 79° 19′) three miles to the north.

[1] *Rec. Geol. Surv. Ind.*, VI, pp. 78-79, (1873).

Subsequently Mr. Hughes[1] gave the records of the borings, and estimated that in no part of the area would the coal seams lie at a greater depth than 900 feet. The borings were commenced on Kamthi rocks, and the record of C bore-hole proved seven feet coal at 85 feet, 17 feet of coal at 129 feet, three feet coaly shale at 243 feet, and six feet of coal at 162 feet—to base of seams in each case. It is unknown to what extent the Barakars were eroded before the Kamthi beds were laid down, but the thickness of the Barakars in the Wardha valley area has been computed as not more than 300 feet, which is similar to that found in the Pench valley tract of the Satpuras.

Other borings have proved four seams each under ten feet thick and in one boring, showing only two seams, the lower is 30 feet thick. As these borings were put down long ago and only actually proved about a square mile, it is not possible to say if there are more than four seams, nor to correlate all of them. The 17-foot seam is recognisable in four of the seven borings. Mr. Hughes thought that the coal would be of similar quality to that in the Wardha Valley fields, and that 38 feet of coal (with partings) represented the stock in these reserves. It can be safely accepted that 18 feet of coal in one, two, or three workable seams, may be expected under an area of six square miles. This will mean a total of 108,000,000 tons and, allowing 50 per cent. for loss, etc., an available reserve of at least 54,000,000 tons. The field, however, lies at a distance of nearly 30 miles from the nearest existing line of railway, and will remain isolated for sometime to come.

Warora Colliery Area.

Much of the area now to be dealt with is obscured by alluvium, and a belt of Deccan trap extends westwards from north-east of Warora. The only outcrops of Barakar rocks are in the Lalghat *nala*, east of Dongargaon railway station (20° 19′ : 78° 57′) and in the Dehwal *nala*, north-west of Aikona (Yekona), respectively, six miles north and W. N. W. of Warora (20° 13′ : 79°), but no successful explorations appear to have been made in these localities. In each case the continuation of the coal measures must be looked for under younger rocks, east of the places mentioned. At Warora

[1] *Mem. Geol. Surv. Ind.*, XIII, pp. 147 and 150, (1877).

itself the coal was found by boring, and, as previously stated, a colliery worked there for over 30 years was finally closed down due to a serious subsidence. It was also thought at the time that the seams were nearly worked out, but this is a question now to be considered.

Between 1870 and 1873, about 40 borings were put down along the western side of the Chanda-Nagpur road near Warora, from near Nandori (20° 12′ : 79° 2′). to near the Dâk Bungalow (20° 14′ 30″ : 79° 1′ 30″). The Nandori boring near mile 70, after going through 216 feet of Kamthi rocks, is thought to have encountered Talchirs. A bore hole just north of Ekarjun (20° 13′ : 79° 1′), west of mile 68, proved 22 feet of coal at 243 feet, and another half a mile to the west of this found 14 feet at 96 feet. The boring near No. 1 pit east of Warora showed 27 feet of alluvium, 145 feet of Kamthi rocks, and had gone through 48 feet coal and partings (two seams—one 15 feet at about 172 feet and a lower 11-foot seam at 218 feet) within 232 feet of the surface. The same eastward dip was indicated by the Kanji borings north-east of Warora. And this same eastward dip is also indicated between Ekarjun and Nandori—a boring south of Ekarjun proved 16 feet of coal at 455 feet and ten feet at 481 feet; another, halfway from mile 68 to mile 69, proved 21 feet at 575 feet and 14 feet at 597 feet. A third boring near mile 69 proved 22 feet of coal at 582 feet and the lower ten-foot seam at 614 feet.

The workings of Warora Colliery were west of the Nagpur-Chanda road, between miles 67 and 68, and between Warora and Ekarjun. The area proved in 1877 was estimated at 420 acres, which, with two seams upper or No. 2 (15-foot) and lower or No. 3 (ten-foot), and allowing for losses, would be roughly over 12,000,000 tons. Between 1873 and 1906, when the colliery was closed down, barely one-fourth of this quantity had been extracted. The influx of water, underground fires, and the working of both seams together finally led to the big subsidence, after which the place was shut down. Judging by the analysis of a sample from the lower part of the No. 2 upper seam (Hughes, 1877)—which shows 13·9 per cent. moisture, 26·5 per cent. volatile matter, 45·4 per cent. fixed carbon, and 14·2 per cent. ash—, the coal was of similar quality to that found in the deeper workings 20 years later. Its calorific value from later assays varies between 5,100 and 5,600 calories, and the moisture percentage was a little less.

The following analyses of coal from the upper (No. 2) and lower (No. 3) seams at Warora are quoted from the Geological Survey Laboratory book, Vol. III, p. 34, under the date 10th March 1897 :—

—	No. 4 Pit, No. 3 seam.	No. 5 Pit, No. 3 seam.	No. 5 Pit, No. 2 seam.	Main dip, No. 3 seam.	Main dip, No. 2 seam.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture . . .	9·78	6·52	7·40	6·38	10·40
Volatile matter . .	29·60	27·10	20·48	19·64	30·40
Fixed carbon . . .	43·72	40·08	36·44	31·62	41·12
Ash	16·88	26·30	35·68	42·36	18·06

Mr. Hughes was of the opinion that there was less prospect of finding coal to the west of Warora, and this is probably correct, owing to the erosion of pre-Kamthi times. However, from the borings now available, it would seam that the Barakars do extend northwards and southward from the old workings of Warora Colliery (abandoned). It is clear that the seams are rather deep to the south-east and, if the Nandori record was correctly read there is a fault in this direction between mile 70 and mile 69. I should not be surprised if the Talchirs near Majri extended northward under the alluvium to Nandori ; nor would this interfere with the possibility of finding coal by boring 250 feet say about mile 3 from Warora on the Wun road ; or about mile 64 on the Nagpur road, preferably a mile east of it, or three miles south-east of Warora. The area south and south-east of Ekarjun has been more or less proved already and, although the coal seams lie at a greater depth, this may be an advantage. The difficulties with water should be less, the moisture percentage in the coal also less, and the seams are evidently somewhat thicker.

With regard to the area immediately north-east of Warora, and between it and mile 66 on the Nagpur road, a boring A, just north of the church (milestone 67) proved three seams—first five-foot at 220 feet, second 10½-foot at 259 feet and a third 11½-foot at 289 feet. Another boring C, east of the road to Nagpur, halfway between

miles 67 and 66, proved four seams—first 4½-foot at 298 feet, second nine-foot at 351 feet, third seven-foot at 370 feet, and fourth four-foot at 415 feet. Another D, west of the road opposite C, struck the first seam four-foot at 157 feet and the second 13½-foot at 335 feet. These were put down in 1922. Their evidence suggests that the pre-Kamthi surface is irregular, but nevertheless the Barakars occur and dip eastwards.

Production of coal from Warora.

The annual production of coal from the collieries at Warora from the time the pits were sunk in 1871 to the date of their abandonment in 1907 is given below :—

Year.	Tons.	Year.	Tons.
	Coal carried by G. I. P. Railway.	1888	?
		1889	?
1873	..	1890	131,493
1874	54	1891	123,669
1875	11	1892	?
1876	1,089	1893	?
1877	28,446	1894	?
1878	35,924	1895	101,383
1879	25,078	1896	121,643
1880	16,039	1897	111,654
1881	57,073	1898	127,237
	Output.	1899	132,080
1882	Serious fire No. 2 seam 100,000 tons coal lost.	1900	133,230
		1901	148,470
		1902	153,336
1883	?	1903	127,623
1884	?	1904	112,319
1885	?	1905	123,015
1886	?	1906	32,327
1887	?	1907	Abandoned.

Rajur or Wun Coalfield.

Within the limits of the Yeotmal (Wun) district of Berar, coal was found in a boring at Zagra between Aikona (Yekona) and Siwni (20° 15′ : 78° 54′), but in a boring further down the Wardha river at Mukta (Mukat; 20° 14′ : 78° 56′), the Kamthi rocks were not pierced at 157 feet. Deccan trap occurs all round this locality, while to the west and south the Pakhal limestones show up from below the trap. However, a narrow strip of Lower Gondwana rocks appears from below the trap near Pisgaon (20° 8′ : 78° 51′) and trends south-east through Wun (20° 3′ : 78° 56′) to the Penganga river near Takli (19° 51′ : 79° 6′). In the Pisgaon-Rajur area these Gondwana rocks which consist of Talchirs, Barakars and Kamthis, dip off the limestones (Pakhals), but are evidently cut off to the dip (south-west) by the strong north-west fault, which again brings in the limestones. This fault trends north-west from between Yanak Hill and Yanak (19° 52′ : 79° 5′) and, passing a mile west of the Kamthi mass of Malhagarh Hill, enters the trap area south of Rajur (20° 7′ : 78° 54′) at Nimbhala Hill. The area south and south-east of Wun is partly concealed by alluvium, and no Barakars or Talchirs are seen in this direction.

Before 1877, several borings were made along the Gondwana outcrop from Papur (Pahapal; 20° 15′ : 78° 49′) to Manki (20° 1′ : 78° 56′) and coal was proved in each area—Pisgaon, Warura (Warad; 20° 8′: 78° 52′), Rajur, Parsora (Palsoda; 20° 5′: 78° 55′) and Wun (opposite Ganeshpur; 20° 3′ : 78° 57′)—except at Manki where the boring was incomplete. About Pisgaon 27 to 31 feet of coal was found at 77 feet from the surface; at Rajur 18 to 30 feet was proved within 160 feet; and at the Ganeshpur bore the same seams evidently were encountered within 245 feet. The coal contains partings, and the Ganeshpur record states it to be coaly shale, but this is questioned by Mr. Hughes.[1] The area to the east and south-east of Rajur, within a mile and a half from the village, was subsequently tested by borings and a colliery was opened here in 1927, soon after railway communication through Wun to Majri on the Balharshah-Wardha line was established.

Immediately south-east of the village of Rajur coal appears to have been met with at from 120 to 160 feet, while further along

[1] *Mem. Geol. Surv. Ind.*, XIII, footnote, p. 47, (1877).

the strike, and somewhat to the dip, the same seam (18 to 30 feet with partings) was proved at 165, 240 and 428 feet. From this data it is safe to assume that in a square mile south-east of Rajur there is ten feet of workable coal or 10,000,000 tons. In the whole tract from beyond Pisgaon to Warora, assuming 20 feet of coal over 12 square miles, the quantity is 240,000,000 tons, of which half may be considered available. The quality of the coal at Rajur (on a dry basis) may be judged by the following analysis (No. 7342, dated 26th April 1927, Chief Engineer, Railway Board)—moisture 10·91 per cent., volatile matter 35·30 per cent., fixed carbon 49·30 per cent., ash 15·40 per cent., calorific value 6,539 calories. It is similar to the coal from Warora, Ballalpur and Ghugus, and is also of non-caking quality.

Remembering always that the Barakars were subject to considerable erosion before the Kamthi sandstones were deposited on them, it would be interesting to know what happens to the outcrop of the Talchirs and Barakars about Wun. The Ganeshpur boring suggests that the latter outcrop must lie east of Wun, and it is reasonable to suggest that this outcrop may turn north-east and north towards Majri (20° 8′ : 79° 0′), where both Barakars and Talchirs occur in association with the Kamthi beds. It is possible that a south-trending fault lies between Wun and Majri, as suggested by the outcrops near Takli along the Penganga river. Nevertheless, the outcrop of Barakars and Talchirs near Takli gives strong support to the view that the coal measures would be found under the Kamthi rocks south-eastward of Wun. The area is a large one and, if truly continuous with that which extends westward from the Telwasa (20° 3′ : 79° 5′) and Ghugus (19° 56′ : 79° 7′) line of Barakar outcrops, very large indeed—about 100 square miles.

With regard to the north-westward extension of the Pisgaon outcrop under the Deccan trap area of Mangli (20° 11′ : 78° 46′) towards Ralegaon (20° 25′ : 78° 32′), no serious attempt has yet been made to prove the possibility of finding the Rajur seam under the trap. The question has been raised on more than one occasion in connexion with Pulgaon (20° 44′ : 78° 19′), but I venture to think that, until the continuation of the Barakars first to Mangli and then to Ralegaon has been proved borings further to the north-west will be purely speculative.

Production of coal from Yeotmal.

The production of coal from Yeotmal (Wun) is shown below :—

Year.	Tons.	Year.	Tons.
1920	225	1924	..
1921	2,345	1925	1,138
1922	3,687	1926	3,704
1923	168	1927	2,222

Period 1920 to 1923 probably refers to output from Ghugus only.

Ghugus-Telwasa Coalfields.

This area is best dealt with in two parts—a northern or Telwasa section, including the outcrops of Majri to Ukni (20° 1′ : 79° 5′) and lying across the Wardha river, partly in Chanda and partly in Yeotmal (Wun); and a southern section including the Barakars from above Nilja (Niljai; 19° 59′ : 79° 6′) through Ghugus to the Penganga about Wirur (19° 51′ : 79° 7′), and again straddling the Wardha river and lying partly in Chanda and partly in Yeotmal. East of the outcrops from Majri to Wirur there is a large tract of Talchir rocks, extending to the Erai river of Chanda town. And it would seem evident from the structure that, although Kamthi rocks appear south of Bhandak (20° 6′ : 79° 7′) and extend northward there is little likelihood of Barakars being found beneath the Kamthis, north of Bhandak and east of the line Majri-Nandori, and so into the Warora area. If this feature persists it will mean that the prospects for coal north-east of Warora will also be limited to this Majri-Nandori line, extended northward.

Mr. Hughes has recorded the finding of a seam of over 50 feet of coal between Majri and the Wardha river at a depth of 75 feet.

Majri-Telwasa.

Recent borings south of Majri have proved coal, and other borings, a mile or so west of the village near the Kona-Naglon track, have shown 15 feet and 57 feet of coal with partings in separate bore-holes. It is presumed that the thick seam represents the two lower seams of Warora which have united southward. These evidences of the existence of thick coal support the idea that the coal measures extend south-westward under the Wardha river into Yeotmal and may be contin-

uous with those of Rajur, as found in the Wun boring at Ganeshpur. In this connexion it is necessary to record that borings for coal on either side of the Wardha river at Agasi and Kunara (Kunad; 20° 5′ : 79° 4′) failed to find the thick seam. It was, however, suspected by Mr. Hughes, that the outcrop would be met under the Kamthis, a little to the west of Agasi. The seam was, in fact, just touched in a boring at Ahiri (Ahari; 20° 4′ : 79° 3′) but was not encountered at Borgaon (20° 4′ : 79° 4′).

Mr. Hughes proved 62 feet of coal with partings in a boring at Junara (Junad), opposite Telwasa (20° 3′ : 79° 5′), where the same seam nearly 59 feet thick had been found on the east bank of the Wardha river. The Barakar rocks are exposed at Chargaon and Dhorwasa, but no coal was proved there at the time of Mr. Hughes' survey. Recent borings show that the outcrop of the Telwasa seam may tough the village areas of both the places named, but, as the dips are westward, the main coal-bearing area lies west of the Wardha river under the Kamthi rocks in Yeotmal. One new boring near Telwasa shows the following :—

	Feet.
Variegated sandstone	59
Dark yellow clay	3
Hard shale	3
Coal	8
Shale	2
Coal	21
Coal and shale	16½
Coal	13
Light grey shale	2
Coal	3
TOTAL	130½

Analyses by Mr. Tween [1] show that the basal section of the coal at Telwasa is better than the upper part; he does not give the moisture content, which is presumably about 10 per cent. The average of the coal samples (from a bore-hole) gave :—33·15 per cent. volatile matter, 43·94 per cent. fixed carbon, an 22·91 per cent. ash. The lower 11 feet of the seam gave an average of about 32·00 per cent. volatile matter, 50 per cent. fixed carbon, and 18·00 per cent. ash. It is probable that, in actual working, a much better quality of coal could be secured from this thick seam of Telwasa-Junad.

[1] *Rec. Geol. Surv. Ind.*, III, p. 49, (1870).

There is an irregularity in the outcrop of the Barakar rocks, between the northern section already discussed and the area now under consideration, at about Ukni (20° 1′ : 79° 5′). But at Niljai a bore-hole encountered the coal at a depth of 86 feet and proved the following section below that depth :— *Coal* 37 feet 4 inches, sandy shale 4 feet 4 inches, *coal* mixed with shale 2 feet 9 inches, shale 4 feet 1 inch, and *coal* 32 feet 9 inches. The section of the seams here agrees with those found at Ghugus and further south at Nakora. The outcrop of a coal seam is seen near Kumbhari (19° 57′ : 79° 6′), and an analysis made from a sample taken by Dr. Blanford showed 14·5 per cent. ash (dry basis). The Ghugus and Nakora (Navkawada ; 19° 55′ : 79° 6′) sections, as given by Mr. Hughes[1], show that the thick seam is really made up of five or six separate beds of coal. The Nakora section is as follows :—

Ghugus section.

Coal seam.	(1).	(2).
	Ft. in.	Ft. in.
Coal	4 0	90 8
Sandy shale	2 10	....
Coal	3 6	....
Dark sandy shale	5 4	....
Coaly shale	3 6	....
Black shale	16 10	....
Coal, inferior	4 0	....
Coal	5 0	....
Sandstone and shale	5 ·0	....
Very dark shale	3 0	....
Dark sandy shale	2 10	....
Coal	21 8	....
White sandy shale	0 2	....
Coal	13 0	....

[1] *Op. cit.*, pp. 32-34.

It will be remembered that the Mayo Colliery (opened in March, 1870) was soon after closed at Ghugus, and the Warora Colliery, 20 miles nearer to the main railway between Nagpur and Bombay, was opened in 1873. Since the Warora Colliery was closed down in 1906, and the Ballalpur area, 36 miles to the south, developed the question of again opening the Ghugus area has been repeatedly considered. New borings were put down after the War, and with the building of a branch railway to Ghugus from Tadali (20° 2′ : 79° 12′) on the Balharshah-Wardha line, a new colliery was established at Ghugus. The new area is about a mile south of the old Mayo pit, and has been made safe against flooding from the overflowing of the Wardha river. Just south of Mayo pit, No. 1 Pit has proved 11 feet of coal at 109 feet, but this is only the top of the thick seam. Further south, No. 3 Pit has been sunk to 264 feet and struck 17 feet 6 inches of coal at 225 feet, but above and below it there is coaly shale and coal, which makes up the so-called thick seam. The coal measures of course extend to the dip under the Wardha river to the west and should be found in the Yeotmal district in the direction of Malhagarh Hill, but it is not known at what depth the coal may be expected.

The quality of the coal from the new Ghugus workings (1), Robertson incline (2), and (3) top and bottom coal in Pits 2 and 3, respectively may be judged from the following analyses:—

—	(1).	(2).	(3).
	Per cent.	Per cent.	Per cent.
Moisture	11·0	14·45	13·56
Volatile matter	34·30	29·40	28·24
Fixed carbon	49·58	57·92	53·56
Ash	16·12	12·68	18·20
Calorific value (calories)	6,114	7,021	6,349

All the samples are of non-caking coal. These analyses are similar to those on record for samples taken from Kumbhari, Telwasa and Majri, and resemble those of Warora and Rajur and Ballalpur, as being of the same seams.

There can be very little doubt that the thick seam outcrop must extend southward from Nakora (Navkawada) and, although not seen at the Penganga river near Kolgaon (? 19° 52′ : 79° 7′), nor at Takli further upstream, it must nevertheless lie to the dip of the Barakar outcrops at those places. The overlap of the Kamthi rocks conceals the coal seam, as is already well known in other places, and almost certainly does so in this area, between the Wardha and Penganga rivers and the north-west trending Yanak fault. Most of the area from the Penganga river on the south, the Yanak fault on the west, and the Majri-Ghugus outcrop to the east, lies in Yeotmal with Kamthi sandstones exposed. As already stated, this is an extensive concealed coalfield averaging 100 square miles. If we reckon a seam of 15 feet thickness, there are 1,500 million tons of coal; and, if one-third is allowed for losses, etc., there are 1,000 million tons of coal available. Surely the possibilities render this one of the most attractive for testing.

Area about Chanda Town.

Chanda (19° 56′ : 79° 18′) is situated on Kamthi rocks, on the eastern edge of a large tract of Talchirs. Outliers of Barakars occur south-west of Chanda about Hingnala (19° 54′ : 79° 17′), and there is an outcrop of these rocks in the Erai river south of Chanda at Charwat (Charvat; 19° 53′ : 79° 18′). Mr. Hughes was never quite satisfied that the sandstones seen at Chanda were Kamthi, because in some ways they resembled Barakars; the matter is of interest in that borings, just north and north-east of Chanda town, have proved the existence of one or two thin (up to two feet) coal seams. And during recent years at least two collieries were working to the east (Mahakali Colliery) and south-east (Babupet), on the outskirts of the town. The seams met with by boring at Mahakali Colliery show 19 feet of coal at 81 feet, and 26 feet of coal at 120 feet (Bore-holes Nos. 9 and 10 respectively) below those proved by the Jharpat *nala* borings.

Although no thick seam has been proved other than at Mahakali, it would appear that exploration to the south-east of Chanda town is likely to be more profitable than to the north and north-east of the town. It is possible that the thin seams above mentioned may represent a basal position in the Barakars, which are overlapped by Kamthi rocks at Charvat and Isapur (halfway to

Ballalpur), and also near Ballalpur, as the borings at Ballalpur in 1900 proved the eastward extension of the coal measures at increasing depths towards Bahmini (19° 50′ : 79° 23′). From this it may be argued that the outcrop has a north-easterly direction and may swing north and north-west towards Chanda. This is of course pure speculation, but the point is worthy of proof by boring, say, in the vicinity of the north or north-east of Ballalpur itself. There is a large area east and south-east of Chanda covered by Kamthi rocks, before the eastern boundary of the Gondwara rocks is met at Kelzar (19° 58′ : 79° 34′). A narrow-gauge line, Bengal-Nagpur Railway, joins Kelzar with Chanda.

Ballalpur (or Ballarpur) Coalfield.

It will be remembered that, in 1870, when Dr. T. Oldham[1] gave a summary of the information then available of the Wardha Valley coalfields, it was thought that the coal seam exposed in the Wardha river near Sasti (19° 49′ : 79° 20′) did not extend eastward into the Chanda district. And Mr. Hughes[2] records that borings put down on the Ballalpur side of the Wardha river to a depth of 236 feet found only two thin seams, nine inches and 18 inches thick. His remarks show that it was in the area east and south of Ballalpur (19° 51′ : 79° 21′), to be examined later and in the area east of Chanda town[3] that prospects of coal were good, but he was careful to point out that the depth to the coal might be great. In 1900, when the question of finding a new area in place of Warora became important, systematic boring was carried out at Ballalpur, and coal found; the first pit was sunk in 1903 and the second in 1906, when Warora was closed down.

One boring opposite Sasti proved two seams, 17 feet and 14 feet, with a sandstone parting one foot thick between them, at 62 feet; but there is a fault between the river and No. 1 Pit which lies nearer and south of Ballalpur. Here eight feet of shale and *coal* were found within 202 feet, and below this four feet *coal*, seven feet shale, four feet *coal*, five feet shale, nine feet *coal*, and seven feet shale at 238 feet. Half a mile east of this, at 546 feet, there was met five feet shale, 1¼ feet *coal*, 1½ feet black shale and 24¼ feet *coal*

[1] *Rec. Geol. Surv. Ind.*, III, p. 48, (1870).
[2] *Mem. Geol. Surv. Ind.*, XIII, p. 37, (1877).
[3] *Op. cit.*, p. 38.

(total depth 578 feet). The colliery at Ballarpur (Ballalpur) has been working ever since. The coal at Sasti has also been opened and worked and transported over the Wardha river by aerial ropeway to Ballarpur colliery. At least two square miles of coal-bearing ground have been proved south-east of Ballalpur, while Messrs. Tata, Ltd., have had under consideration the opening of a concession between Bahmini and the Wardha river about Dudholi (19° 48′ : 79° 22′), where the Balharshah-Kazipet Railway crosses the Wardha river into Hyderabad.

It was at Ballalpur nearly 20 years ago that hydraulic stowing of sand in the mine was first carried out in India by the present General Manager, Mr. R. S. Davies.[1] The annual production of coal from these mines, Ballalpur-Sasti, varied from 150,000 to over 200,000 tons during the first ten years after the War. The quantity from Sasti may be taken as about one-fifth that from Ballalpur, or roughly from 25,000 to 40,000 tons. The quality of the coal from Ballalpur may be gauged from the two analyses given below :—

—	(1)	(2)
	Per cent.	Per cent.
Moisture	10·12	9·64
Volatile matter	32·02	35·35
Fixed carbon	42·03	50·50
Ash	15·83	14·15
Calorific value (calories)	6,026	6,371
Caking property	*Nil.*	*Nil.*

Production of coal. The production of coal from the collieries of Ballarpur are given below :-

Year.	Tons.	Year.	Tons.
1903	..	1907	18,103
1904	90	1908	45,299
1905	148	1909	88,237
1906	916	1910	93,276

[1] *Trans. Min. Geol. Inst. Ind.*, X, Pt. 2, (1916).

Year.	Tons.	Year.	Tons.
1911	96,603	1923	112,362
1912	86,417	1924	127,545
1913	80,959	1925	150,490
1914	89,292	1926	142,935
1915	94,880	1927	158,617
1916	84,889	1928	175,872
1917	95,303	1929	202,061
1918	135,375	1930	211,980
1919	126,366	1931	223,025
1920	128,162	1932	217,421
1921	171,425	1933	256,344
1922	132,680		

It has been already stated that two square miles of coal-bearing ground has been proved south-east of Ballalpur. This, for a seam 20 feet thick, will mean reserves of 40,000,000 tons; but, if the area east of Chanda and Ballalpur to the gneissic boundary is included, the area is of the order of 200 square miles. As this tract is covered by Kamthi rocks, whose thickness probably does not exceed 700 to 800 feet, it is possible that, if any coal underlies them, the seams will be within a workable depth. We may estimate ten feet of coal under this tract; with these figures the reserves, down to the latitude of Kothari (19° 48′ : 79° 30′) will be of the order of 2,000 million tons, *i.e.*, greater than in the tract between Ghugus and Malhagarh hill in Yeotmal. Moreover, southward of Kothari there is still another large tract, on the Chanda side of the Wardha river, and also in the area south of Sasti on the west side of this river. These areas will now be considered.

Reserves of coal.

Wamanpalli or Lathi Area.

The next exposure of Barakars in the Wardha valley, south of the Ballalpur-Sasti outcrop, is that at the bend between Lathi (19° 34′ : 79° 30′) and Wamanpalli (19° 34′ : 79° 33′), opposite Antargaon railway station, on the Kazipet-Balharshah

CHAPTER 17.

PRANHITA-GODAVARI VALLEY COALFIELDS OF HYDERABAD STATE AND MADRAS.

Introduction.

The area now to be considered is a continuation south-eastwards of that in the Wardha Valley tract already discussed. The same geological formations and structural features are present. The basement rocks are Archæan gneisses, but the floor of the Gondwana strata is largely of unfossiliferous Pakhal limestones and shales and the Sullavai sandstones; and these rocks, together with the overlying Gondwanas, appear to lie in an old rift valley, due to pre-Gondwana faulting. The Upper Gondwanas, west of Sironcha, continue to Nagaram (18° 21′: 80° 26′). The Lower Gondwanas, represented extensively by the Kamthi sandstones, continue far beyond Beddadanol, south of the Godavari river, and are succeeded in that direction by Upper Gondwanas of the East Coast type. Exposures of Talchirs and Barakar (coal measures) are seen at rare intervals—the former as far south-east as Kishtaram (17° 39′: 81° 4′) and the latter to Beddadanol (17° 14′: 81° 15′). But it is clear from the distribution of these exposures that they had suffered considerable erosion in pre-Kamthi time. In addition there has been post-Kamthi faulting. It is because of the irregular nature of the Barakar rocks under the covering of Kamthi beds that the greatest uncertainty exists with regard to the search for coal measures below them, in spite of the fact that the Kamthi rocks may not be of great thickness. And this uncertainty increases as we go down the valley of the Godavari from Sasti (19° 49′: 79° 20′) to Beddadanol.

It has already been stated that a search for coal, near Kota[1] (18° 54′: 79° 58′) was made by boring as far back as 1841. At that time there was a rumour of the occurrence of anthracite at Dantimpili (said to be near Tandur; 19° 9′: 79° 27′). These details are given more fully in the *Madras Journal of Literature*

[1] W. Walker, *Journ. As. Soc. Bengal*, X, p. 341, (1841).

and Science, XVII, page 261, (1856); and also (Philip Wall) in XVIII, page 256, (1857). The area[1] was visited and mapped between 1859 and 1880 by officers of the Geological Survey of India. By that time the several occurrences of coal measures and of coal had been noted, and Dr. King had discovered the valuable coalfield at Yellandlapad (17° 36′: 80° 19′), known as the Singareni coalfield. Singareni (17° 31′: 80° 17′) is five miles away from the collieries to the S. S. W. near Karepalli railway station. It will be convenient to discuss the Godavari Valley coalfields in two sections—those in the Nizam's Dominions in Hyderabad State, and those in the Madras Presidency. As in the case of Sasti and Ballalpur there are other outcrops which extend from the Hyderabad side of the Godavari into Madras, and these will require separate treatment.

COALFIELDS IN HYDERABAD (DECCAN) STATE.

General.

Gondwana strata, chiefly Kamthi sandstone, and occasionally Maleri and Kota beds, extend as a continuous strip from the Wardha valley through the Nizam's Dominions into Madras. In Hyderabad State several sections may be recognised:—(1), roughly eight miles wide for 20 miles from Sasti to Antargaon (19° 33′: 79° 29′); then (2), roughly 25 to 30 miles wide from Antargaon, for 125 miles, to a line from the Talperu (Tal river) near Lingala (18° 1′: 80° 50′), across towards Singareni; then (3), in a narrow outcrop, eight miles wide for 20 miles to the Murer river about Kottagudam (17° 32′: 80° 38′) and lastly (5), where it expands again to over 20 miles and after another 40 miles, passes under the Upper Gondwanas of the East Coast west of Rajahmundry. It cannot be assumed that this enormous tract of nearly 4,500 square miles, in Hyderabad State and Madras, is all underlaid by coal measures. Of this area 200 square miles, chiefly of Upper Gondwanas about Sironcha, are in the Central Provinces and perhaps 600 square miles within Madras. The remaining 3,800 square miles lie in the Nizam's Dominions and of this not less than 3,000 square miles being covered by Kamthi rocks. In so large an area there are surprisingly few outcrops of Barakars and Talchirs, and two of

[1] W. King, *Mem. Geol. Surv. Ind.*, XVIII, p. 178, (1881).

these are outliers, away from the main spread of the Gondwana strata.

The following areas of coal measures are, for convenience of description, treated as separate coalfields. It is of course evident that most of them are merely outcrops of Barakars from beneath the same mantle of Kamthi rocks, and are really parts of a great coalfield. Beginning in the north there are :—(1) Sasti-Rajura area ; (2) Antargaon-Aksapur ; (3) Tandur ; (4) Chinur-Sandrapali ; (5) the Karlapalli or Kamaran outlier ; (6) an outcrop east of Bandala ; (7) Muttapuram-Allapalli ; (8) opposite Lingala (Tal river) ; (9) Yellandlapad (Singareni) coalfield ; (9) Murer river about Kottagudam ; (10) Kunnigiri or Maddukuru outcrop ; (11) Damarcherla or Madavaram. Among these, only one—Kottagudam—lies only on Kamthi rocks, and in this case, although borings proved the coal, and pits were sunk, and rail connexion established, yet it was decided to neglect the area for the present, as the Tandur area was found more attractive. This was largely due to the completion of the Kazipet-Balharshah Railway, which now gives through communication from Wardha to Bezwada and the Madras coast on one hand, and with Hyderabad and the Mahratta country on the other.

It should be stated at this stage that the discovery of most of those coal-bearing areas and of possibly still larger (but concealed) coalfields in Hyderabad State, is entirely due to the work of Dr. W. T. Blanford, Mr. T. W. H. Hughes and especially to the labours of Dr. William King.[1] Were it not for their labour and discoveries these coalfields might have remained unknown for many years. Their field work of 50 years ago was found so good that it has not been necessary to re-survey any of the coalfields from the Wardha Valley area to the lower Godavari tract.

Sasti-Rajura Area.

The Sasti coal is often spoken of as the Ballalpur coal, but it was on the Sasti side of the Wardha river that the coal was first found. Also, in 1870 and 1874, when borings were put down near Ballalpur and in the Sasti area, the thick seam was proved only on the Hyderabad (Sasti) side. Today the pits at Sasti are worked by the company established at Ballalpur and the coal is taken

[1] *Mem. Geol. Surv. Ind.*, XVIII, Pt. 3, (1881).

over the Wardha river by an aerial ropeway. The early borings (1871-74) were put down near Sasti (19° 49′: 79° 20′), Manoli (19° 51′: 79° 19′), Kolgaon (19° 52′: 79° 19′), Kadoli (19° 52′: 79° 18′), Paoni (19° 49′: 79° 17′), Gauri (19° 48′: 79° 18′) and Rajura (19° 47′: 79° 22′); but of the 52 borings it was discovered that many were badly placed, *i.e.*, 50 to 100 feet below the coal horizon.[1] It was then thought that the area west of Sasti was not as good as the area south of the Wardha river, eastwards from Rajura to Chunala (Kanala; 19° 47′: 79° 24′) and Chanaka (19° 46′: 79° 26′) and southwards to Hirgaon (19° 44′: 79° 27′). This represents an area of roughly 200 square miles, west of the Wardha river, south-east from Sasti.

In the Sasti vicinity it was considered that 1½ square miles contained 50 feet of coal. The two shafts at Sasti had met a 27-foot seam at 78 feet; but this was known to be only a part, as the top of the seam had been denuded. The thick seam is banded with thin beds of shale and inferior coal, although the greater portion of the whole thickness consists of hard, good coal. It is to be remembered that a 60-foot seam was proved near Paoni, but, owing to the pre-Kamthi erosion, there is some uncertainty as to its continuity. Dr. Blanford[2] had noted the good quality of the Sasti coal in the Wardha river outcrop. Two recent (1922) analyses of the coal mined at Sasti Colliery are shown below:—

—	1	2
	Per cent.	Per cent.
Moisture	12·06	11·91
Volatile matter	31·76	31·95
Fixed carbon	52·71	50·20
Ash	15·13	17·85
Calorific value (calories)	6,148	6,177
Caking property	*Nil.*	*Nil.*

The second analysis was done in 1929 and both were made at the Government Test House, Alipore.

[1] *Mem. Geol. Surv. Ind.*, XIII, p. 55, (1877).
[2] *Rec. Geol. Surv. Ind.*, I, p. 25, (1868).

As seen from Mr. Hughes' geological map of the Wardha Valley coalfield, the Kamthis overlap the Barakars south of Rajura and lie on the Talchirs for several miles; but, in the vicinity of Wirur (19° 38′ : 79° 26′), Barakars again appear from below the Kamthis and between them and the Talchirs to the west. This southern tract will next be discussed as the Antargaon-Aksapur coalfield.

The production of coal from the colliery at Sasti, opposite to Ballarpur and across the Wardha river, is shewn in the data below: all this coal was transported by aerial ropeway to Ballarpur and despatched from there.

Production of coal.

Year.	Tons.	Year.	Tons.
1920	27,745	1927	25,477
1921	42,674	1928	35,615
1922	38,522	1929	47,455
1923	29,204	1930	46,808
1924	25,050	1931	53,417
1925	38,153	1932	61,184
1926	28,034	1933	49,794

Antargaon-Aksapur Coalfield.

The Barakar outcrop near Wirur continues south-eastward to Antargaon (19° 33′ : 79° 29′), and is seen in the Wardha river at Lathi ghat. South of Antargaon it is overlapped by Kamthis which spread on to the Sullavai sandstones to the west. It will be noticed that, west of Antargaon, the Barakars have also overlapped the Talchirs on to the Sullavais; and south-east of Antargaon the Upper Gondwanas (Maleri and Kota beds) come in over the Kamthis. Between Kothapet railway station (19° 20′ : 79° 29′), which is on Kamthis, and Aksapur (Anksapur; 19° 20′ : 79° 20′), there is an outcrop of Barakars, resting on the Sullavai to the north and dipping south under Kamthis, which in turn dip under Upper Gondwana rocks. Although the Antargaon and Aksapur coal measure outcrops are not continuous, it is almost certain that they connect beneath the Kamthi beds.

As previously stated, a six-foot seam (with a nine-inch parting of shale) occurs below Lathi ghat, the analysis[1] of which on a dry basis gave :—moisture 8·7 per cent., volatile matter 28·25 per cent., fixed carbon 51·26 per cent. and ash 20·49 per cent. I am not sure whether this is part of the thick seam or another. There is an anticlinal structure west of Antargaon where, in the Anar range (Kondai-ka-pahar), a five-foot seam outcrops a short distance up the hill. No coal seams appear to outcrop in the Aksapur area, and, as no exploration by boring has been made, it is difficult to give any useful opinion as to the amount of coal that might be expected in the Antargaon-Aksapur area.

Tandur Coalfield.

There is evidently a synclinal south of Aksapur, as the Barakars reappear about 12 miles to the south, at Abbapur (Abapur; 19° 13′: 79° 20′). These coal measures extend south-east from beyond Kairgura (Aregura; 19° 15′: 79° 16′) through Tandur (19° 9′: 79° 27′) to east of the Belampalli railway station (19° 3′: 79° 29′), and there is a small outlier three miles to the west, near the hamlet of Waripet (19° 3′: 79° 26′). Talchirs show to the west of the main outcrop, and the Barakars, which dip north-east, are followed in that direction by Kamthis and these by Upper Gondwanas (Maleri and Kota beds). Mr. Hughes[2] records the occurrence of a coal seam 15 feet thick near Aregura (Kairgura), of which the analysis gave :—moisture 9·4 per cent., volatile matter 32·8 per cent., fixed carbon 45·6 per cent. and ash 12·2 per cent. He also noted an outcrop near Golet (Guloti; 19° 14′: 79° 24′). With the completion of the railway (1928) from Kasipet to Balharshah, passing through Tandur, the Hyderabad (Deccan) Co., Ltd., have opened up the Tandur coalfield.

The length of the Barakar outcrop is about 24 miles, and we may assume that the coal seams will be within workable depths under the Kamthi sandstones, *i.e.*, for three miles to the dip (north-east). The field has recently been proved and two workable seams found within the Barakar outcrop. About 140 feet of strata separate the upper from the lower seam. The thickness of the seams vary

[1] Hughes, *op. cit.*, p. 64.
[2] *Rec. Geol. Surv. Ind.*, XI, p. 20, (1878).

and their quality is reported to be similar to those of the Wardha Valley. The Chief Mining Engineer, Railway Board, writing of this newly opened colliery, says that Messrs. Best and Company have a large area at Tandur and also a very modern colliery as far as equipment is concerned. An average analysis of the coal would run :—moisture 7·25 per cent., ash 16·10 per cent., volatiles 28·50 per cent., fixed carbon 55·40 per cent., and 6,463 calories (dry basis).

The production from Tandur began in 1931 but is included in the output for Singareni. In 1932 the production from Tandur was 126,471 tons.

South of the eastern end of the Tandur coalfield there appears to be a fault, trending E. S. E. to the southern edge of the Sullavai (Vindhyan) inlier near Chinur (18° 51′ : 79° 48′), and throwing the strata down to the south-west. In this southern tract, and including the villages of Sarangpali (18° 59′ : 79° 28′), Yenkatapuram (18° 55′ : 79° 31′) and Tetmatla (18° 47′ : 79° 32′) on the Godaveri, there are possibilities of coal. No Barakar rocks have been definitely recognised and the Kamthis overlap on to the Talchirs ; but to the dip (eastwards), at the places named, bore-holes would probably find the coal measures or at least would give clear data as to the extent of the pre-Kamthi erosion. The fact that Barakars occur near Chinur on the upthrow side of a fault supports the view that coal measures will be found in the area between Tandur and the Godavari river, in an area of about 100 square miles.

Chinur-Sandrapali Area.

Chinur is situated on Kamthi rocks, but just to the west of it the Barakars appear with Talchirs below ; these rocks in turn rest on the Sullavai sandstones of the Sankaram inlier. The Talchirs and Barakars dip north-east and strike south-east across the Godaveri to beyond Sandrapali (18° 47′ : 79° 52′). In the river below the outcrop fragments of coal are commonly found, but the exact position of the seam appears to have remained undiscovered. At the river above the Talchir outcrop Upper Gondwana (Maleri) strata have been faulted in upstream ; it is thus clear that the main coal measure area lies downstream towards Sironcha (18° 5[illegible] : 79° 58′). South of Sandrapali the Sullavai sandstones are

again present in another inlier. The total length of the Barakar outcrop between Chinur and Sandrapali is roughly 14 miles, and it is possible that the coal measures will be within workable depths under the Kamthis to near Sironcha—this would give an area of quite 100 square miles in which coal might be expected. But owing to the isolated position of the area, the fact that it is traversed by the Pranhita and Godavari rivers, that there are railway facilities at Tandur and in the area south of it, there is little likelihood of borings being put down in the Chinur-Sandrapali area, unless those to the west prove disappointing. This seems unlikely with careful prospecting.

South of the Godavari, above its junction with the Pranhita and west of the river below the confluence, there is a large area of Kamthi rocks 16 to 20 miles wide, and these continue across the Pengadi valley, east of Sullavai (18° 12′ : 80° 5′) for over 70 miles south-east to below Cherla (18° 5′ : 80° 49′), in the Godavari valley, above the junction with the Talperu (Tal river). The east boundary is hidden by the alluvium of the Godavari, beyond which are the Pakhal limestones and shales and sandstones of the Albaka facies. The west boundary shows the Kamthis overlapping on to Talchirs, and beyond them on to the Sullavai, and even on to the older Pakhals. No Barakars appear north of the Pengadi in an area quite 600 square miles in extent. It is difficult to fix the amount of overlap of the Kamthis on the hidden Barakar coal measures; but that coal seams must exist in the Barakars below the Kamthis cannot be seriously questioned.

Karlapalle or Kamaram Outlier.

South of the Laknavaram or Pengadi river there are several places, in which coal or Barakar outcrops have been noted, although the greater part of the area is covered by Kamthis, within 20 to 24 miles west of the Godavari river. There is one small outlier with Talchirs, Barakars and Kamthis in the Karlapalli Vagu, a tributary of the Pengadi river, halfway between Karlapalle (18° 8′ : 80° 9′) and the hamlet of Kamaram (17° 58′ : 80° 12′). Dr. King[1] discovered this little field from reports made by the Tahsildar of Kandiconda, but the local Kois were already acquainted with the occurrence of coal in that locality. Dr. King[2]

[1] *Rec. Geol. Surv. Ind.*, V., p. 50, (1872).
[2] *Mem. Geol. Surv. Ind.*, XVIII, p. 184, (1881, reprint 1930).

says of this field that the area is about 156 acres; there are two seams of coal; the total coal is estimated at 2,265,120 tons of which half is thought to be of fairly good quality. In his earlier report the total thickness of Barakars is shown as 305 feet, as below: –

Sandstones (top)	140 feet.
Coal	9 feet.
Sandstones	15 feet.
Coal	6 to 18 inches.
Sandstones	60 feet.
Coal	6 feet.
Sandstones	74 feet.

From this the coal may be taken as two seams, nine feet and six feet, which gives 3¾ million tons. The dips are high and the strata somewhat heavily watered. These factors and the difficult country render it unattractive at present.

Bandala-Allapalli Area.

East of the outlier of the Karlapalle vagu, and south of the Laknavaram or Pengadi, coal has been reported in the Kinarsani Vagu, three miles east of Bandala (18° 6′ : 80° 16′), and further down the valley between Gundala (17° 55′ : 80° 20′) and Muttapuram (17° 54′ : 80° 23′), and as far as Allapalli (17° 50′ : 80° 29′). The so-called Bandala coalfield was not seen by Dr. King[1] and the report quoted is that of Mr. W. H. Heenan who says that coal was found by the local Koi people and that the occurrence is near Bollapalle (18° 3′ : 80° 19′).

'Upon leaving Bollapully which is about three and a half miles north-west of the hills where the newly-discovered coal exists, the path crosses the bed of the Kumarsani river, and, passing over a couple of miles of broken and much disturbed ground, enters the bottom of a deep ravine, at the head of which the coal is exposed in a small cave, having about 70 feet of superincumbent sandstone forming its roof. The lower portion consists of Damuda and the upper of Kamthi sandstones, with a thin layer of laterite at the surface.'

From this account Bandala would seem to be incorrect and possibly the true position of the cave with coal showing in it, is three miles south-east of Bollapalle. No specimens appear to have been analysed, but the seam is stated to be six feet thick with a low dip to the east.

[1] *Mem. Geol. Surv. Ind.*, XVIII, p. 185, (1881).

Before the discovery of Bollapalle (or Bandala ?) was reported, Dr. W. T. Blanford[1], had investigated a reputed find of coal, lower down the Kinarsani valley at Allapalli; he stated that these rumours were based on fragments of shaly coal which had been washed down the river. Dr. King[2] also visited the Allapalli area in a march up the Kinarsani valley, where he noted the likeness of the rocks to the Barakar outcrops of Lingala (18° 1′: 80° 50′) on the Godavari river. However, he was unable to find any coal outcrop but from the fact that fragments of coal have been found down to Allapalli, and that a seam six feet thick has been noted further upstream, it would seem that certain Barakar coal measures must crop out in the Kinarsan valley. The country is still somewhat isolated, and there seems to be no immediate need for the area to be re-surveyed, the observations made 50 to 60 years ago did not lead to any detailed investigation of the Kinarsani valley.

Area opposite Lingala.

Dr. Blanford stated that fragments of coal had been found for several years in the bed of the Godavari, close to where the Tal river (Talperu) joins it from the north; and Mr. P. W. Wall had noted them in 1857 when on his way to Kota near Sironcha. Dr. Blanford visited the place in 1867 on his way down the Godaveri; at his suggestion an exploration on the Madras shore of the river bed, revealed two coal seams, neither more than two feet thick, with dips towards the Hyderabad side (south-west). A third seam of five feet of coal of better quality than the two lower seams was found in the middle of the river bed. Finally Mr. Vanstavern, the Executive Engineer engaged in the exploration, found a fourth seam, two feet, on the Hyderabad side. As these investigations were carried out from Lingala (18° 1′: 80° 50′), on the British side of the Godaveri, they refer properly to the coal in the Madras Presidency and will be mentioned later.

In 1880, when Dr. King visited this area opposite Lingala, the Nizam's officers were endeavouring to prove the seams on their side of the Godaveri river, *i.e.*, the tract south-east of Kondayyagudem (18° 1′: 80° 48′); but the data then available appears to have been no more than that given by Dr. Blanford a decade before.

[1] *Rec. Geol. Surv. Ind.*, IV, p. 82, (1871).
[2] *Op. cit.*, p. 186.

Thus the whole of the area between the Godaveri, opposite Lingala and westward beyond the Kinarsani valley, and northward to the Pengadi or Laknavaram river--something like 800 square miles of country covered by Kamthi rocks, under which coal measures almost certainly occur remains to be explored. In this tract some evidence exists that the Kamthi rocks are as much as 950 feet thick.[1] Reckoning only five feet of coal under 800 square miles there are possibilities of 4,000 million tons, if the Barakars occur under the Kamthis and are no worse than the outcrops seen to the east and west--near Lingala and in the Karlapalle valley respectively.

Singareni Coalfield.

This outlier of Lower Gondwana rocks--Talchir, Barakar and Kamthi—near Yellandlapad (17° 36′: 80° 19′), about 5 miles north-north-east of Singareni (now also Karepalli railway station; 17° 31′: 80° 17′), was discovered by Dr. William King[2] in 1872. It is a narrow strip about 11 miles long and two miles wide, giving a total of 19 square miles, but the Barakar coal bearing beds appear to occupy only eight square miles. The discovery was the result of an exceptionally dry period during Dr. King's visit when the pools in the streams were so low that exposures hitherto concealed were visible. The original sample gave an analysis (dry basis) showing—moisture 6·0 per cent., volatile matter 22·6 per cent., fixed carbon 62·4 per cent. and ash 15·0 per cent. At Dr. King's suggestion the Government was induced to prospect this area by boring and four seams within 50 to 250 feet of the surface, in two areas were proved. The top seam of six feet was good coal; the second and third seams averaged three feet thick each; while the bottom or thick seam was quite 34 feet of solid coal of the same quality as that given in the analysis above.[3]

Subsequent borings[4] have shown that there are six seams below the seam found to be 67 feet thick. This Singareni seam is followed downwards by two thin seams; then comes the New seam about five to 8½ feet; below that the Stone coal 3½ to 7½ feet; next below the King seam six to seven feet of excellent coal; and at the base a Bottom seam over 2½ feet thick, 340 feet below

[1] *Rec. Geol. Surv. Ind.*, V, p. 53, (1872).
[2] *Loc. cit.*, p. 65.
[3] *Mem. Geol. Surv. Ind.*, XVIII, pp. 187-188, (1881).
[4] *Rec. Geol. Surv. Ind.*, XXVII, Pl. 3 (1894).

the Thick seam, and 140 feet below the King seam. It is thus 200 feet from the base of the Thick seam to the top of the King seam. The section at Oosman Pit ($1\frac{1}{2}$ miles north-east of Huserakapalli tank) shows about 100 feet of Kamthis; the top of the Thick seam at a depth of 464 feet with the base at 537 feet (*i.e.*, 73 feet coal and shale); the King seam is at 726 feet ($7\frac{1}{2}$ feet thick). At the new Strutt Pit (north of the Polampali-Yelandla fault), No. 152 boring shows about 45 feet of Kamthis, and the top of the Thick seam (group) is at 421 feet and the base at 494 feet; (in this 73 feet of the Thick seam there are two sandstones, ten feet and 15 feet respectively). The King seam occurs at 708 feet (*i.e.*, 214 feet below the Thick seam).

Between 1873 and 1886 the Yellandlapad or Singareni coalfield was proved by borings when Mr. T. W. H. Hughes was in charge of the operations for working the coal. In 1887 he reported that the reserves in the Thick seam and the King seam might safely be taken as 156,000,000 tons. Later Dr. Saise (1893), estimated 45,000,000 tons in the King seam alone. Up till then it had been the practice to work the coal entirely by inclines, but after 1894 shafts were sunk and an extraction of 75 per cent. made, by leaving rather small pillars. In 1903 a somewhat serious subsidence gave warning and the method of working was modified. The introduction of hydraulic stowing was tried recently but has not been continued. If the strata above the King seam has broken by settlement it will not be safe to work the Thick seam, even if it is good enough to work. Here then is an interesting example of an original estimate of 156 million tons being first reduced to 45 million tons and then to 36 million tons available in actual working.

Attention has been given almost entirely to the King seam which, in Dr. Saise's report[1], is given as having 7·6 per cent. moisture, 10·65 per cent. ash, 25·25 per cent. volatile matter, and 56·50 per cent. fixed carbon. He reckoned an average thickness of $4\frac{3}{4}$ feet of coal in nine square miles, and, allowing 20 per cent. for losses, estimated the reserves at 36,000,000 tons. This was in 1893 (40 years ago), and he stated that the upper seams will receive attention in time to come. About 20 million tons of coal have been produced from the Singareni collieries since 1893, when the Hyderabad (Deccan) Mining Co., Ltd., appear to have begun raising the coal.

[1] *Rec. Geol. Surv. Ind.*, XXVII, p. 54, (1894).

Analyses of the King seam coal, by Messrs. Hughes and Davies in 1923 and 1924, from the Main Dip of Polampali Pit and from Strutt Pit, are given below :—

—	1	2
	Per cent.	Per cent.
Moisture	7·18	6·47
Volatile matter	28·75	28·58
Fixed carbon	50·30	53·98
Ash	13·77	10·97
Calorific value (calories)	5,984	6,300

Picked specimens of (1) vitrain, (2) normal coal and (3) carbonaceous shale from the King seam, obtained by the writer in 1925, gave the following results :—

—	1	2	3
	Per cent.	Per cent.	Per cent.
Moisture	7·46	5·72	3·64
Volatile matter	28·16	22·02	14·44
Fixed carbon	59·32	59·28	34·82
Ash	5·06	12·98	47·10
Specific gravity	1·33	1·41	1·78
Caking property	Strong.	*Nil.*	*Nil.*

From the data given regarding the production of coal from the King seam half the estimated reserves had been obtained by 1924. At that time borings had been made in various other areas with a view to opening a new mine when the King seam at the Singareni collieries should be exhausted. This would suggest that the Thick seam has either been damaged by the extraction of the King seam below or that its quality is not good enough. However, as already stated, a colliery has been opened in the Tandur area by the same company. The Singareni collieries, at the Yelandlapad, are connected by a branch railway with the Nizam's Guaranteed State Railway at Dornakal (17° 27′ : 80° 9′) 15 miles to the south-west.

Two important facts emerge from the data obtained in the working of the King seam; one is that the Barakars are clearly upwards of 700 feet thick and the other is the absence of igneous intrusions. It is clear that the Kamthis are relatively thin in this area—barely 200 feet—but they are much thicker in the main area further east. The pre-Kamthi erosion is as clear in this area as in those already dealt with, from the Wardha Valley fields southward.

Production of coal. The production of coal from Singareni collieries since they were opened in 1886 is shown below :—

Year.	Tons.	Year.	Tons.
1887	3,259	1907	414,221
1888	13,382	1908	444,211
1889	59,646	1909	442,892
1890	125,486	1910	506,173
1891	144,668	1911	505,380
1892	149,601	1912	481,652
1893	157,421	1913	552,133
1894	240,525	1914	555,991
1895	292,915	1915	586,824
1896	262,681	1916	615,290
1897	365,550	1917	680,629
1898	394,622	1918	659,122
1899	401,216	1919	662,196
1900	469,291	1920	666,335
1901	421,218	1921	646,047
1902	455,424	1922	604,358
1903	362,733	1923	629,225
1904	419,546	1924	619,725
1905	454,294	1925	629,724
1906	467,923	1926	609,745
		1927	681,736

Year.	Tons.	Year.	Tons.
1928	699,150	1931	704,158[1]
1929	768,420	1932	593,466
1930	765,490	1933	519,443

Kottagudem Area.

In 1925 borings had proved coal measures under about 150 feet of Kamthi rocks at Kottagudem (17° 32′: 80° 38′), a mile west of the confluence of the streams forming the Mureru river. The locality is about 24 miles east of the Yellandlapad outlier of the Singareni collieries. The King seam was proved at a depth of nearly 400 feet, but the Thick seam was found badly split up into bands of shale, coaly shale and coal. Pits were sunk and a branch line built to Kottagudem from Karepalli on the Dornakal-Singareni line. It was known that the strata were very heavily watered, as the sinking pumps had at times to deal with 40,000 gallons an hour. It was not considered quite the most suitable area, and with the construction of the railway from Balharshah to Kazipet *viâ* Tandur it was decided to abandon the Kottagudem development and open up the Tandur coalfield. The machinery was transported and the whole of the branch line picked up and used for the Tandur project. Perhaps this closing down at Kottagudem will discourage any further exploration for coal in the tract south of the Mureru river for many years. It must be stated that this tract, to the Madras border although probably heavily waterlogged, nevertheless almost certainly contains coal.

Kannegiri-Maddukuru Area.

The southern part of the extensive spread of Lower Gondwana (Kamthi) rocks, which have been followed south-east from the Wardha valley into that of the Godaveri river, begins at the Mureru or Murer river. An outlier of Talchir rocks is present in the lower part of the Kinarsani river, just before it joins the Mureru; and Barakars appear at Daorpali (Devarapalle; 17° 38′: 81° 1′), on the Madras side of the Godaveri river, and evidently connect with the same strata seen at Damarcherla and Madhavaram (17° 36′:

[1] Includes Tandur output.

81° 5′), on the right bank a few miles lower down; a second outcrop of Barakars is shown on Dr. King's map at the north-east corner of the Kannegiri hills near Maddukuru (17° 21′ : 80° 41′), 4 miles south-east of Sandragunda (17° 23′ : 80° 38′); and lastly there is an outcrop of Barakars, six miles east of Ashwaraopet (17° 15′ : 81° 8′) about Beddadanol (Bedadanuru; 17° 14′ : 81° 14′). Except for these small areas, the Kamthi sandstones overlap all round their margins on to the Archæan gneisses. No Sullavai or Pakhal strata are seen, and it is quite impossible to say whether the Barakars are continuously present below the Kamthis or only to be found in isolated patches, which escaped the pre-Kamthi denudation.

No coal appears to have been found in the Kannegiri outcrop, which Dr. King[1] noted as a favourable indication that coal might occur in this vicinity. No borings appear to have been put down and this Chundragunda (Sandragunda) neighbourhood is quite ten miles south of the Mureru valley at Kottagudem, where the attempt to establish a colliery was abandoned, after coal had been proved and shafts sunk to the supposed King seam.

Damarcherla-Madhavaram Area.

The Barakars found on the Hyderabad side of the Godavari river, about Damarcherla and Madhavaram, were partially tested by boring in 1871, when the operations were transferred to the north or British side of the river.[2] No coal outcrops and only thin seams were found in a boring 193 feet deep. Later, in 1874, borings, under the Nizam's officers, were made further west in the area of Kamthis, three miles from Ravigudem (17° 38′ : 80° 56′), evidently up the Pamula valley.[3] Here, in a tract about five miles by two, three seams of coal were stated to have been found:—top seam, one foot at 247 feet; next seam, four feet at 272 feet; and third seam, six feet at 314 feet. It is clear that the coal measures have not been sufficiently proved, but it is of interest that they are present at so shallow a depth, westward of the outcrops of Damarcherla and those north of the river in British territory about Totapalle (17° 37′ : 81° 4′). Seeing that the Godavari river is

[1] *Mem. Geol. Surv. Ind.*, XVIII, p. 194, (1881).
[2] *Rec. Geol. Surv. Ind.*, IV, p. 60, (1871).
[3] *Mem. Geol. Surv. Ind.*, XVIII, p. 193, (1881).

navigable to the sea from below the *First Barrier* at Dummagudem, 12 miles above Bhadrachalam (17° 40′ : 80° 53′), good workable coal in the area tested on the Nizam's side of the river could be easily taken down the Godavari to Rajahmundry, or to the sea at Cocanada or Masulipatam.

Bedadanuru-Ashwaraopet Area.

This is the third area where coal is found outcropping on the British (Madras) side of the Nizam's borders, with the Barakars dipping under Kamthis into Hyderabad State. Ashwaraopet (17° 15′ : 81° 8′) is situated on Kamthi sandstone, while the Bedadanuru (Beddadanol) exposures of Barakars lie six miles to the east. It is the most southerly exposure of Barakars in the Indian peninsula, but the borings for coal were disappointing, as only four thin seams were met with (one 4½ feet at 188 feet). Picked pieces from the bore-hole debris gave :—12·8 per cent. moisture, 25·0 per cent. volatile matter, 37·0 per cent. fixed carbon and 25·2 per cent. ash. These are the results of the search on the Madras (Bedadanuru) side of the border. It has evidently not been considered worth while to try any deep borings in the direction of Ashwaraopet.

It must, however, be remarked that the finding of the coal measures here in the Ashwaraopet-Bedadanuru area ; in the Damarcherla-Madhavaram area ; and in the Kannegiri-Kottagudem tract, is indicative of a widespread occurrence of coal measures. The area involved is of the order of 500 square miles of Kamthis, under which the Barakar coal measures may be expected. The great thickness of the Barakars in the Singareni (Yellandlapad) coalfield, with the best seam far down towards the base, should be an incentive to prove the Ashwaraopet area and east of it, by one or two borings, capable of going through the Barakars, or proving the strata to a depth of 1,500 feet.

COAL IN THE MADRAS PRESIDENCY.

General.

The history of coal discoveries in the Madras Presidency is of considerable interest as each reported occurrence has been treated as of possible importance. Unfortunately most of the rumours

have been based on the *appearance* of rocks by those who imagined that they were competent to judge of such matters in Archæan and Pre-Cambrian rocks. In two or three instances borings, begun in Upper Gondwana rocks, failed to find the Barakars below within 1,000 feet of the surface, or at least did not encounter any coal seams within this depth. And lastly, in three localities where the Barakars had been recognised and proved to contain workable coal, the extent of the outcrop in two of them was too restricted for profitable mining, and in the third case the quality of the coal and its thickness were not sufficiently good for successful exploitation. As several years have elapsed since the question of these Barakar coal measures was dealt with, the subject is now re-examined.

Barakars in Godavari Valley.

All the Barakar outcrops of the Madras Presidency occur in the East Godavari district. The first is that of the Tal river (Talperu) at its junction with the Godavari near Lingala (18° 1′ : 80° 50′); the next that below Bhandrachalam near Daorpali (Devarapalle; 17° 39′ : 81° 1′); and the third that of Beddadanol (17° 14′ : 81° 14′) in the Bedadanuru reserved forest. All three localities are on the borders of Hyderabad State, and the coal measures dip under the Kamthi rocks which cover extensive areas in the Nizam's Dominions south and west of the Godavari river. In each of the instances given the appearance of the Barakars on the British side of the river or boundary supplies valuable data to the Nizam's officers, these rocks would otherwise have remained unsuspected beneath the Kamthis of south-eastern Hyderabad.

Lingala Exploration.

The discovery of coal fragments in the bed of the Godavari, where the Talperu joins it near Lingala (18° 1′ : 80° 50′), was known before 1857, when Mr. P. W. Wall travelled through on his way to examine the reported discovery of coal at Kota beyond Sironcha. In 1867 Dr. W. T. Blanford was asked by Colonel Haig to assist in finding the seam, and, owing to his suggestions coal was found in four places in the bed of the Godavari, on the

removal of the covering sand.[1] Four seams were finally found in strata dipping westward—two two-foot seams on the British bank, one five-foot seam in the middle of the river, and a two-foot seam on the Hyderabad bank. Dr. King mentions explorations in 1880, on the Nizam's side of the river, but little information was then available. Mr. R. R. Simpson[2] in reply to enquiries made by the Geological Survey of India in 1897 wrote that, the Collector of the East Godavari district had stated :—

'The coal-bearing rocks on the British side cover about 5 square miles. A seam of coal was struck in 1891, and a trial pit, 11 feet deep, sunk. Seventy tons of good coal were taken out. The coal was 5 feet thick (including a bed of shale 6 inches thick, 2 feet from the floor). Allowing ⅓ loss on mining, this field on the British side is estimated to yield 8 million tons of saleable coal.'

Ganaparam Area.

This village lies next to Tatpali (Totapalle; 17° 37′ : 81° 4′), opposite to Damarcherla, which is south of the Godavari. The area was examined by borings under Dr. W. T. Blanford[3]; and, in a boring 86 feet deep, two seams of three feet each, separated by six feet of carbonaceous shales, were found within 53 feet of the surface. Fragments of coal washed from the bore-hole sample gave :— moisture 10·8 per cent., volatile matter 26·9 per cent., fixed carbon 42·7 per cent. and ash 19·6 per cent. The results were not very encouraging, but in spite of this Dr. Blanford felt that further exploration was desirable. In 1874 explorations were made by the Nizam's officers, in the area of Kamthi rocks to the west, and three seams proved—one foot, four feet, and six feet—of coal of unattractive quality. The exact position of the bore-hole is not clearly stated.

In answer to an enquiry by the Geological Survey of India in 1897 the Collector of the East Godavari district wrote that :—

The extent of the coal-bearing rocks on the British side is about 16 square miles, of which about 10 square miles may be taken as containing workable coal. A seam of fine quality has been found opposite the village of Rajahzompalli, and over 2,000 tons were taken out of the trial pit. It averages 5 feet 6 inches in thickness. This seam is estimated to yield, after deducting ⅓ for waste, about 24 million tons of coal.'

[1] *Rec. Geol. Surv. Ind.*, IV, p. 50, (1871).
[2] *Mem. Geol. Surv. Ind.*, XLI, p. 97, (reprint 1922).
[3] *Rec. Geol. Surv. Ind.*, IV, p. 61, (1871).

Mr. R. R. Simpson[1] however, adds :—

'According to the official statistical returns of output 3,657 tons of coal were raised from the Rajahzompalli pits between the years 1891-95. In the latter year, however, the enterprise was abandoned.'

Beddadanol Area.

The name is spelt Bedadanuru (17° 14′ : 81° 14′) on the new maps. It is six miles east of Ashwaraopet, in which vicinity Dr. W. T. Blanford[2] thought the rocks might be Barakars. The Beddadanol (Bedadanuru) locality was mentioned by Dr. Blanford[3] and specially visited by Dr. W. King[4] who confirmed his opinion and estimated that 5¼ square miles were occupied by these Beddadanol beds (Barakars). No coal was seen, and the thickness of these supposed coal measures estimated at least 300 feet, and borings recommended to this depth of 300 feet. The borings were put down by Mr. Vanstaveren and four seams proved, but only one was of workable thickness. This was met at 188 feet[5] and was 4½ feet. Analyses of fragments taken from the washings of the boring gave :— moisture 12·8 per cent., volatile matter 25·0 per cent., fixed carbon 37·0 per cent. and ash 25·2 per cent. Further details are given later with a map of the bore-hole positions.[6] Dr. King had then pointed out various peculiarities regarding the coal measures of Singareni—that coal was often not visible at the surface, that shale beds were also not conspicuous, etc. He did not know then that the Barakars there were over 750 feet thick, and that the best seam (named after him) occurred almost at the bottom of the Barakars. With these points in mind and knowing the accessibility of the Bedadanuru area both from Rajahmundry in the east and Ellore in the south, it is an interesting point whether the outcrop of Barakar rocks (at Bedadanuru) has been fully explored.

The great area of Kamthi rocks covering the 20-mile tract between Bedadanuru and Chintalapudi (17° 3′ : 80° 59′) continues south-east and passes under strata of the Upper Gondwana formations. The search for coal measures under the Kamthi (or

[1] *Op. cit.*, p. 96.
[2] *Rec. Geol. Surv. Ind.*, IV, p. 52, (1871).
[3] *Supra*, V, p. 24, (1872).
[4] *Idem*, p. 112; also see VI, p. 57, (1873).
[5] *Rec. Geol. Surv. Ind.*, VII, p. 159, (1874).
[6] *Supra*, XV, p. 202, (1882).

Chintalapudi) sandstones need not be restricted to the vicinity of the Bedadanuru outcrop, if borings up to 1,500 feet are contemplated, although much greater thicknesses of the overlying rocks may be expected elsewhere. If a purely speculative effort were made just south of Jangamregudem (Zangareddigudem; 17° 7′: 81° 18′) and if no Barakars were found within 1,000 feet, or if the Kamthis (Chintalapudi) sandstones proved to be of this thickness further efforts in this direction need not be considered. Chintalapudi itself might be chosen as an alternative site to the one suggested. As a third possibility for purely experimental boring, Mulagalampalle (17° 11′ : 81° 14′), four miles south of Bedadanuru, is also suggested, and with it perhaps Kamayyapalem, half-way between Bedadanuru and Ashwaraopet. It is almost certain that coal should be found in the last two places, but the finding of workable coal in the former would be of greater value.

Upper Gondwana Areas.

The Bedadanuru beds (Barakars) are covered by the Chintalapudi sandstones (Kamthis) which continue south-east and pass under the Upper Gondwanas near Ragavapuram (17° 2′: 81° 20′). These Upper Gondwana rocks spread south-west from the Godavari, above Rajahmundry to Golapili west of Ellore. In both directions they rest directly on the Archæan (Bezwada) gneisses. From the trend of the belt of Kamthi rocks up the Godavari valley, it is apparent that, if these rocks continue south-east, they must lie under the successive formations exposed between Ragavapuram and the mouth of the Godavari. These formations are as follows:—

Alluvium of Godavari delta		Miocene.
Rajahmundry sandstones		
Kateru (Deccan) traps and inter-trappeans		Senonian.
Dudkur Infra-trappeans		Aptian ? to Cenomanian.
Tripati sandstones	Upper Gondwanas	Portlandian.
Ragavapuram shales		Bathonian.
Golapili sandstones		Charmouthian.
Chintalapudi sandstones (Kamthi)		Lower Gondwanas.
break		
Bedadanuru coal beds (Barakars)		

It is thus seen that, if the Barakars extend under the younger formations, the last practical place for boring will be west of Raga-

vapuram. However, the Upper Gondwana rocks have been found beyond the Kistna delta at intervals to the west of Madras and as far as the Cauvery valley in Trichinopoly. In none of these outcrops have any Lower Gondwana strata been seen. Consequently it is of interest to refer to two localities west of Madras where a search for coal was made.

Kilacheri.

Kilacheri (Kizhachcheri; 13° 2′ : 79° 51′), Chingleput district, about 30 miles west of Madras. In 1891, in boring for water at the Monastery at Place's Gardens, by the Father Superior, Mr. R. B. Foote thought that the indications (carbonaceous shales) suggested the presence of Lower Gondwana coal measures (Barakars). The boring was started in the Sripermatur beds and carried to 307 feet, having passed through 25 feet of bituminous shale. The matter was taken up by the Madras Government and the boring continued to 660 feet, without encountering any coal seams.

Arkonam.

Arkonam (13° 6′ : 79° 41′). Near Arkonam in the North Arcot district and about 42 miles west of Madras, a number of borings appear to have been put down on an outcrop of Upper Gondwana (Sripermatur) beds. The cores of these borings were examined by Mr. H. Walker in 1911. He was of the opinion that even in the deepest bore-hole, 991 feet, all the rocks passed through belonged to the Upper Gondwanas. As no workable seams of coal have been found in the Upper Gondwana strata of the Wardha-Godavari valley, nor in the Upper Gondwanas of the East Coast, it is evident that these efforts have been directed to the finding of Lower Gondwana rocks.

From the statements made earlier in this section and from the results of these boring experiments, it is clear that it will be useless to search for coal measures of Barakar age in the Madras Presidency, outside the limits of the Kamthi outcrop between Bedadanuru and Chintalapudi in the Yerrakalva valley, along the borders of the Godavari and Kistna districts.

Coal in Purana Rocks ?

When discussing the coal measures in Central India, mention was made of the baseless rumours of the finding of coal in strata of Vindhyan age (in the Bijaigarh shales and the Semri series),

It was shown that pyritic and carbonaceous shales do occur in those Purana rocks, but that there was no locality known where any seam of coal had been found. Similar 'finds' of coal have been long in circulation in connection with the Purana rocks of certain localities where nothing has been found to justify such opinions.

Jaggayyapeta.

Jaggayyapeta (Juggiapet; 16° 53′ : 80° 5′) in the Kistna district, just north of the hair-pin bend or Chintapalli peninsula of the Kistna, is one of the places where coal has been supposed to occur in rocks which may be Kadapah or, at least, not newer than Kurnool in age. The history of this case is fully discussed by Mr. H. B. Medlicott[1]. The earliest record is dated 1851 and endorsed 'Lieutenant Applegath's supposed coal sites'. The next evidence dated 1861 is 'Captain F. Applegath's description of the geological strata on the north bank of the Kistna'. After this matters took a more official form, and in 1866 Major Applegath submitted a memorial to Government for further exploration. In 1868 Dr. T. Oldham, accompanied by Colonel Applegath visited the locality and stated 'that, in my opinion, there is no ground for any hopes whatever of coal being found within this area.....'. In 1870 Colonel Applegath was permitted to exploit the area with a detachment of Sappers and Miners, but no coal was found. In spite of this he continued 'to express his firm belief in the existence of coal here'. The area was examined about the same time by Messrs. W. King and Bruce Foote[2] and the rocks were proved to belong to either the Kadapahs or Kurnuls. In 1873 Colonel Applegath submitted a fresh map of the area to Government, and in 1874 marked for Mr. H. B. Medlicott the places for borings which were made by Mr. Vanstaveren. His account was submitted to Major Hasted, R.E., and this officer's report states that 'no coal-bearing rocks nor outcrops of coal or any combustible matter was met with'. The case seemed settled when, in 1882, at a meeting of the Society of Arts in London, a lecture was delivered by Professor V. Ball on the 'Mineral Resources of India', when Major General F. Applegath protested against the insufficient exploration of the Kistna locality near Jaggayyapeta and declared his position unshaken as a discoverer of coal in Madras.

[1] *Rec. Geol. Surv. Ind.*, XV, pp. 207-216, (1882).
[2] *Mem. Geol. Surv. Ind.*, VIII, p. 293, (1872).

Chennur (Chinna Mazapully; 14° 35′ : 78° 49′), five miles north-west of Cuddapah town in the Cuddapah district, was brought to notice as a possible coal-bearing area by Dr. Hunter in 1871. The rocks involved belong to the Kurnul system and are very similar to those of the Kistna about Jaggayyapeta already discussed. The original 'discoverer' of the promising indications of coal in this locality was a Mr. Adams, a coal miner from Chanda. The material from the pits east of the village was examined by Mr. R. Bruce Foote[1], but he was unable to discover even 'the faintest indication of coal or coal shale'.

Chennur.

Coal in Archæan Gneisses ?

From what has been recorded above it will not be surprising to discover that there have been false reports by misguided persons of coal in the Archæan gneisses. I have previously mentioned the hoax perpetrated by a convict in the Midnapur jail, but there the cover of alluvium materially helped to obscure the case. There is no such obscurity about the following instances both in the Madras Presidency and in Mysore State.

Gooty (15° 7′ : 77° 38′) in the Bellary district. In this case a Sergeant Fenner reported to Dr. Hunter that he had picked up pieces of coal, five miles north-west of Gooty on the Adoni road. Dr. Hunter visited the place and also found a few pieces of coal, and at his suggestion the place was examined by Mr. R. Bruce Foote.[2] The locality is on gneissose granite; and greenstone (?dolerite) dykes and quartz veins are also present in the vicinity; the nearest newer rocks are Puranas (Cuddapahs), older than those (Kurnools) of the two localities already mentioned, and quite eight miles away to the east. The coal fragments found by Sergeant Fenner and Dr. Hunter had all gone when Mr. Foote examined the place (Yerragudi Hill). A small trap dyke was pointed out as the most favourable indication of coal. Mr. Foote satisfied himself that coal was not *in situ* in the area, and that the samples supplied had dropped off a cart or carts conveying coal from Mr. E. W. Barnett's coal depot at Gooty to Adoni. Fragments were still to be seen

Gooty.

[1] *Rec. Geol. Surv. Ind.*, IV, p. 17, (1871).
[2] *Loc. cit.*, p. 16.

where the Gooty-Adoni road crossed the railway. Mr. Foote was able to show that the coal fragments on the site of the coal depot were identical in appearance with the specimens obtained by Dr. Hunter from Yerragudi Hill.

Kaligiri.

Kaligiri (Caligherry; 14° 49′: 79° 42′) taluk in the Nellore district. Mr. R. R. Simpson[1] mentions that Mr. G. Powell discovered what seemed to him pieces of coal in four places in this taluk. The material when examined by Mr. P. W. Wall proved to be black tourmaline. Among the specimens seen by Mr. Wall, however, was a piece of asphalt, and Dr. Hunter showed Mr. Wall a piece of lignite from the Tada taluk.

Yernagudem.

Yernagudem (16° 59′: 81° 30′) taluk in the Kistna district. Dr. W. King[2] mentions the occurrence of large masses of tourmaline of very black colour from near Koyegoodem (?Koyyalagudem; 17° 7′: 81° 25′) which 'have over and over again been sent to me by the district officials as coal'. And in this connexion Dr. King added as a footnote :—

'Some years ago, when arranging the collection in the Madras Museum, I found a piece of tourmaline labelled as coal, and as forwarded by the late Mr. Boswell, M.C.S., who was one of the advocates for the occurrence of coal in the Kistnah District.'

COAL IN MYSORE STATE.

Kamasamudram.

As far back as 1871 Dr. A. Hunter[3], Superintendent of the School of Art, Madras, described as coal some green chlorite which he had received from a Dr. Orr of Bangalore. About the same time, in 1873, a Mr. Michael Lavelle is reported to have 'suspected' the existence of coal in the neighbourhood of Kamasamudram or Kamsandra (12° 52′ 30″: 78° 12′) in Bhowringpet taluk, Mysore. After half a century, in 1924-25, this Kamasamudram locality was again brought to public notice by Mr. C. W. Schomburg. He was so convinced that coal would be encountered in this vicinity within 350 feet of the surface that he persuaded the Mysore

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 105, (reprint 1922).
[2] *Rec. Geol. Surv. Ind.*, VII, p. 160, (1874).
[3] *Indian Economist*, II, p. 210, (1871).

Durbar to sanction the sinking of a shaft. The area is situated on Archæan rocks, largely consisting of hornblende—schists and dykes of hornblendic rock. Notwithstanding this, a sample of coal was 'produced' from the shaft and its analysis is given as—moisture 1·85 per cent., volatile matter 41·90 per cent., fixed carbon 30·76 per cent., and ash 25·49 per cent. with strong caking properties. Now such a coal is very like some of the low moisture Eocene (Tertiary) coals of the Punjab and Baluchistan. No normal Lower Gondwana (Palæozoic) coal has the proportion of volatile matter greater than that of the fixed carbon. As there are no outliers of either Gondwana or younger rocks in this area, it would appear that the shaft had been deliberately 'salted'. The matter was examined by Mr. H. M. Hance in his capacity of consulting engineer, and considered worthless by him and an investigation was carried out by the late Rai Bahadur Vinayak Rao of the Geological Survey of India, who also reported it as worthless. It should be added that so persuasively did Mr. Schomburg press his recommendation for sinking the shaft and of other exploration in this connexion, that in spite of the representations of the Mysore Geological Survey Department, to the contrary, he was able to induce the Mysore State Dewan to 'prove' his *discovery*. The whole affair was so obviously absurd, from a geological point of view, that the sample of coal 'produced' cannot be treated seriously.

CHAPTER 18.

SUMMARY OF COAL RESERVES IN LOWER GONDWANA COALFIELDS.

Introduction.

The detailed particulars already given in this memoir furnish a summary of the reserves of coal of various classes in the Lower Gondwana rocks of India. And from the descriptions given it is possible to obtain an idea of the facilities or the difficulties that may be expected in working the coal seams of any area. Nevertheless, it is usual to compile a table showing the total coal in each coalfield, to which one may refer for statistical and other information on the reserves of coal in India. It must be pointed out, however, that a simple table showing the total tonnage of coal may give a misleading idea of the kinds or grades of coal involved. Such tables do not give the minimum thickness of good workable seams nor the workable section of thick seams. They do not indicate the ash percentage of the coal, nor do they differentiate between non-caking coal and that which yields a hard metallurgical coke. To incorporate all these items requires an elaborate table or several brief tables of each grade of coal.

Tonnage of Coal.

In estimating the total coal in a seam in square miles, acres, or bighas (roughly three bighas to an acre, but it varies), much, of course, depends on the weight of a cubic foot of the coal. It has been usual[1] to take the specific gravity of good coal, with volatile percentages higher than 30, as 1·375; and to assume 1·4 as the specific gravity of low (under 30 down to 20 per cent.) volatile coal of good quality; and to accept a specific gravity of about 1·45 for inferior coals generally. Dr. L. L. Fermor (see footnote)

[1] This is adopted by Mr. E. R. Gee [*Mem. Geol. Surv. Ind.*, LVI, p. 282, (1932)], and based on some analyses by A. Tween [*Rec. Geol. Surv. Ind.*, X, p. 156, (1877)] and other data. According to Dr. L. L. Fermor [*Rec. Geol. Surv. Ind.*, LXIII, Pl. 9, (1927), a higher figure 1·397 say 1·40 would be better. It is probably best to adopt this figure of 1·40 as the specific gravity of all good quality Lower Gondwana Coals.

suggests 1·40 as the most reliable specific gravity for all first class coals. These particular precautions are usually only applied to small areas and in connexion with special sections of a coalfield. The rough and ready rule that a one-foot seam yields a million tons per square mile is very useful for calculations such as are given here. A one-foot seam would thus hold 1,562 (say 1,500) tons per acre or 520 (say 500) tons per bigha, but these are not easy figures to remember; and it is best to make a calculation based on specific gravity for such small areas. Another well-known rough rule is 130 tons per inch (thickness of seam) per acre. In none of these calculations is any allowance made for loss in working, and for this reason some mining engineers estimate 100 tons per inch per acre for safety. In the tables given below, and in this memoir generally, I have followed the first rough rule of a million tons per foot per square mile, and have made no allowance at all except for the coal extracted from small or well developed coalfields.

Total Coal Reserves.

It is impossible to estimate the actual amount of coal in the seams in the Lower Gondwana rocks even in seams upwards of one foot. We can arrive at some kind of approximation by taking Mr. Hughes' total of 30,000 square miles of coal-bearing rocks, *i.e.*, after deducting 5,000 square miles for Assam and other areas, and reckoning an average thickness of four feet of coal throughout this very liberal spread. This would give 120,000 million tons of coal of all kinds in the Lower Gondwana rocks, mainly in the Barakar series. But, as quite considerable areas remain to be tested and that in others the seams are known to lie at unworkable depths, the above total may be considered as of academic interest. A more reasonable total, but nevertheless still depending on uncertain data, is given below :—

1. Darjeeling and Eastern Himalayan region . . .	100 million tons.
2. Giridih, Deogarh and Rajmahal Hills	250 million tons.
3. Raniganj, Jharia, Bokaro and the Karanpura fields .	25,650 million tons.
4. Son Valley—Aurunga to Umaria and Sohagpur . .	10,000 million tons.
5. Chhattisgarh and Mahanadi (Talcher)	5,000 million tons.
6. Satpura region—Mohpani to Kanhan and Pench Valley	1,000 million tons.
7. Wardha-Godavari-Warora to Bedadanuru . . .	18,000 million tons.
TOTAL .	60,000 million tons.

Reserves of Workable Coal.

If we restrict the totals to include only those seams over four feet thick and averaging 20 per cent. ash (not exceeding 25 per cent. ash on a moisture free basis), and lying within 1,000 feet of the surface, the above estimates will probably become modified to those given below :—

1. Darjeeling foothills Lisu-Ramthi area	20 million tons.
2. Giridih, Jainti and Rajmahal Hills	80 million tons.
3. Raniganj, Jharia, Bokaro and Karanpura fields . .	10,150 million tons.
4. Son Valley-Hutar to Umaria and Sohagpur . . .	2,000 million tons.
5. Chhattisgarh and Mahanadi (Talcher)	1,200 million tons.
6. Satpura region-Mohpani to Kanhan and Pench . .	150 million tons.
7. Wardha-Godavari-Warora to beyond Singareni . .	6,400 million tons.
TOTAL .	20,000 million tons.

Perhaps a larger amount of coal might be included as under the basaltic lavas in the Rajmahal hills, within a workable depth. Also the total permitted to the Satpura region is admittedly too low; but as no deep borings have proved the Pench Valley along its northern edge, it is not safe to add to the totals of a difficult area. Finally, the reserves given for the Wardha-Godavari Valley *appear* far too high, but here the conditions are very attractive for comprehensive exploration and on the evidence the total is perhaps an underestimate and not an exaggeration.

Reserves of Good Quality Coal.

In these estimates the thickness of the seams is taken as upwards of four feet and, because of the better grade of coal, a depth of 2,000 feet is allowed. The quality is taken on an ash per cent. of 16 (moisture-free-basis), but a certain amount of latitude has been allowed in this connexion with coals outside the Giridih and Damodar Valley fields. The reserves in Bokaro include the coal proved by Bokaro-Ramgarh, Ltd., in the western end of the coalfield. Also a liberal total has been given to the Karanpura fields because boring samples always show 3 to 4 per cent. more ash than those cut in the workings of a seam. The extensive burnt outcrops in the North Karanpura suggest good coal, not the so-called second-class coals in some of the seams of that large coalfield. As usual, no allowance is made for loss anticipated in working, although the coal extracted since each field was opened has been deducted. With these obser-

vations and qualifications, the following totals have been arrived at :—

1. Giridih and Jainti	40 million tons.
2. Raniganj	1,800 million tons.
3. Jharia	1,250 million tons.
4. Bokaro	800 million tons.
5. Karanpura (North and South)	750 million tons.
6. Hutar, Johilla, Burhar	50 million tons.
7. Kurasia, Jhilmili, etc.	30 million tons.
8. Talchir to Korba	200 million tons.
9. Mohpani, Kanhan-Pench	30 million tons.
10. Ballalpur-Singareni	50 million tons.
TOTAL .	5,000 million tons.

Reserves of Good Caking Coal.

The coal here recognised is a coal of similar ash content to that of good quality coal and, also of a character, when subjected to destructive distillation, which yields a hard coke suitable for iron-ore smelting in a blast furnace. Now it is very difficult to obtain from ironmasters an accurate definition of the characteristics which define such a coke. In consequence of this, a low ash (under 21 per cent.) content, a fine porous texture, a silvery appearance and strength (hardness and toughness) to resist crushing, are taken as the chief factors involved in classifying hard cokes. And it is on such a basis that the following reserves of caking coal have been estimated :—

1. Giridih	30 million tons.
2. Raniganj	250 million tons.
3. Jharia	900 million tons.
4. Bokaro	320 million tons.
5. Karanpura	not estimated.
TOTAL .	1,500 million tons.

The caking coal in the Karanpura coalfields may prove to be important, as it is known that coke from the Argada and Sirka seams can be made in 'chatties' if the dull bands are excluded. And analyses of the Gidi (Sirka), Bhurkunda, Simana, Kursi and other seams suggest that the coal from these seams may also yield a hard coke when opened and when mining advances below the zone of weathering. In the case of the Bokaro coalfield it is now known that the Kargali seam is of good caking quality, if the thin

bands of dull coal are separated. It is also certain that some of the coal in the western part of the Bokaro field is also of caking quality. In Jharia the best known caking coals are found in one or other of the following seams—X to XVIII, including XIV A; although these seams may not yield a caking coal everywhere in the field. In the Raniganj coalfield in certain places, the following seams, or sections of them, have yielded a good caking coal—Dishergarh, Sanctoria, Begunia, Laikdih, Ramnagar, and the lower part of Damagaria. In the Giridih field all the caking coal is now won from the Lower Karharbari seam.[1]

Losses in Working.

It has already been stated that no allowance has been made throughout these estimates for possible loss in mining, but a deduction has been allowed for the coal actually removed from the more important coalfields. To show how misleading allowance for loss in working may be, I have placed on record (below) the history of five coalfields which have been worked over periods exceeding 20 years. In these cases—Giridih, Daltonganj, Mohpani, Warora and Singareni —I try to show how the original estimates of the coal reserves have actually compared with the coal extracted. And I have thus tried to make it clear that the life of some coalfields depends not on the total reserves, but on the reserves in one or, perhaps, two seams. With even as high a percentage extraction as 67 per cent., from definite areas in these seams, before the coalfield is abandoned, the coal obtained will be a fraction of the total reserves of the whole field. Taking the Giridih coalfield first:—

Giridih coalfield.

In 1894 this coalfield was considered to have the Lower and Upper Karharbari seams, the Bhaddoah main, and other Hill seams. The estimated reserves were placed at 124 million tons in all these seams, of which about 83 million tons were considered recoverable. The total extraction to date (in 40 years) is probably less than 32 million tons. The reserves to-day are computed at about 35 million tons, so that 48 million tons are written off instead of 32. At the same rate of exploitation, it is thought that the field will be exhausted within 25 years—in getting, say, another 24 million tons out of the remaining 35 million tons. Thus it

[1] *Rec. Geol. Surv. Ind.*, LVI, pp. 301-304, (1928).

means that 50 million tons in all will be got from an original total of 124 million, or from an available total of 83 million tons, *i.e.*, somewhat less than 50 per cent. This is a relatively high percentage of extraction for the Indian coalfields.

Daltonganj coalfield.

This coalfield, opened in 1842, was said as far back as 1872 to contain 18 million tons of coal. The estimate of the reserves was revised in 1890 when a total of 160 million tons were given. Shortly after, as the result of bore hole records, it was stated that nine feet of coal in one square mile (nine million tons) could be counted on. As the exploitation of this field has slowly declined, it is to be assumed that the coal and the mining operations are not attractive. It is doubtful if two million tons in all have been taken from this coalfield, so that on any estimate of total reserves the percentage extraction is small—not 25 per cent.

Mohpani coalfield.

The mines at Gottitoria were valued for sale to the Great Indian Peninsular Railway in 1903-4 and estimated to contain over seven million tons of coal. Owing it is said to the high cost of working, they were closed down and abandoned in 1927, after the extraction of a million tons. Here then is a coalfield which had been worked since before 1870 and which after a good area of coal had been finally located was abandoned within the next 30 years. In this case the percentage extraction was barely 15 per cent.

Warora coalfield.

The colliery at Warora was established in 1873 and finally closed down in 1906, as the result of a serious subsidence, following an underground fire. The two seams in this area were estimated to contain 12 million tons of coal in 420 acres. Of this only three million tons had been extracted at the time the place was abandoned. It may be added that the area under which coal has been found by boring is larger than the 420 acres of the colliery concession. Thus at best an extraction of only 25 per cent. of coal was effected before the coalfield about Warora was abandoned.

Singareni coalfield.

This coalfield was known to contain four seams in 1877, when it was estimated that the available reserves in the Thick seam and King seam were upwards of 156 million tons. By 1894 it was proved that there were three other seams and that the King seam alone contained 45 million tons. It is safe to say that the raisings from the King seam, which alone is worked, have totalled under 20 million tons. The Hyderabad (Deccan) Mining Co., Ltd., have recently opened a new colliery at Tandur in another field, so that it is assumed that the resources of the King seam are in sight of becoming uneconomical to extract more fully, and neither the Thick seam nor any others in this field are now found commercially attractive. It will thus appear that perhaps 50 per cent. of the King seam reserves will be obtained, while all the rest of the seams will be abandoned. This, on a minimum total of 156 million tons, is barely a 15 per cent. extraction from the Singareni coalfield.

Percentage Extraction of Coal.

It has already been said that mining engineers usually estimate the reserves of coal in the seams at tons per inch per acre, with an allowance of about 25 per cent. towards loss. But, from the examples given in the above paragraphs it is clear that it is usually one seam in a coalfield that ultimately makes the field, and, when this is worked out, the coalfield may be considered as worthless. After all deductions in arriving at the totals of available coal (meaning usually ⅔rds of the full amount) it cannot be said that this coal is actually available. There is invariably some unforeseen event—fire, flood, strike or period of bad trade—which renders some coals liable to remain unsold. The allowance for buildings, railway sidings, and barriers between properties often totals 15 per cent. of the calculated reserves, and thus roughly ten per cent. of the so-called available reserves and so takes the percentage from 66 to 56 of the total as available coal. Even the losses of one ton per ton extracted rarely appear to be enough in the case of individual seams. But when it is a matter of the proportion of coal in the calculated reserves of a field with two or more seams, it seems doubtful if we can count on even 30 per cent. In making forecasts of reserves of coal, these are important

considerations and it seems simplest and safest to state the calculated reserves without making any allowance at all. One serious subsidence, due to inefficient working, will lead to the loss of a large area in the coal reserves of a colliery, while an uncontrolled underground fire may result in the loss of the whole colliery, which is equivalent to a whole coalfield of the types mentioned above.

Production of Coal.

In the last chapter of this memoir, I have given a brief statistical summary of the output of coal from the Lower Gondwana coalfields for a period of 56 years since 1878. Earlier statistics are also given but these are largely fragmentary and the total involved is relatively small and thus more or less negligible. To assist the reader who may be interested in the production, utilisation and export of Indian coal during the period since the war the data given on pages 350 to 355 will serve :—

Output of Gondwana coalfields for the years 1919 to 1933.

—	1919. Tons.	1919. Per cent. of Indian total.	1920. Tons.	1920. Per cent. of Indian total.	1921. Tons.	1921. Per cent. of Indian total.	1922. Tons.	1922. Per cent. of Indian total.	1923. Tons.	1923. Per cent. of Indian total.
Bengal Bihar and Orissa—										
Bokaro	722,682	*3·19*	857,522	*4·78*	929,143	*4·81*	1,637,171	*5·46*	1,060,366	*5·39*
Daltonganj	63,250	*0·28*	39,113	*0·22*	36,590	*0·19*	31,933	*0·17*	11,815	*0·06*
Giridih	950,045	*4·20*	831,293	*4·63*	818,580	*4·24*	659,101	*3·47*	713,598	*3·58*
Hutar	..	..	..	..	..	..	..	..	..	..
Jainti	152,941	*0·69*	118,651	*0·66*	105,652	*0·55*	96,612	*0·51*	82,166	*0·42*
Jharia	12,145,917	*53·68*	9,294,040	*51·74*	10,068,856	*52·16*	9,936,299	*52·27*	10,346,015	*52·63*
Karanpura	..	..	..	..	..	..	..	..	..	..
Rajmahal Hills	1,909	..	960	..	2,170	*0·01*	2,801	*0·01*	2,635	*0·01*
Ramgarh	..	..	6,863	*0·04*	..	..	4,565	*0·02*	4,197	*0·02*
Rampur (Raigarh-Hingir).	45,574	*0·20*	36,987	*0·21*	77,277	*0·40*	68,618	*0·36*	50,796	*0·26*
Raniganj	6,815,126	*30·11*	4,997,679	*27·82*	5,211,855	*27·00*	5,203,214	*27·37*	5,557,424	*28·28*
Talchir	..	..	..	..	..	..	..	..	4,816	*0·02*
Burma—										
Loi-an (Kalaw)	..	..	..	..	300	..	172	..	895	*0·01*
Central India—										
Sohagpur	..	..	..	..	37,060	*0·19*	42,693	*0·22*	80,125	*0·41*
Umaria	182,141	*0·80*	158.051	*0·88*	154,974	*0·80*	118,538	*0·62*	95,825	*0·49*
Central Provinces—										
Ballarpur	126,366	*0·56*	128.162	*0·71*	171,425	*0·89*	132.680	*0·70*	112,362	*0·57*
Hoshangabad	..	..	..	..	..	..	..	..	..	..
Mohpani	85,299	*0·38*	83,335	*0·47*	89,623	*0·47*	84,996	*0·45*	87,387	*0·44*
Pench Valley	285,356	*1·26*	279,483	*1·56*	449,311	*2·33*	453,484	*2·39*	346,094	*1·76*
Shahpur	..	..	..	..	210	..	1,069	*0·01*	2,063	*0·01*
Yeotmal	..	..	225	..	2,345	*0·01*	3,687	*0·02*	168	..
Hyderabad—										
Sasti	..	..	27,745	*0·15*	42,674	*0·22*	38,522	*0·20*	29,204	*0·20*
Singareni	662,196	*2·93*	666.335	*3·71*	646,047	*3·35*	604,358	*3·18*	629,225	*3·21*
TOTAL GONDWANA BEDS.	22,238,802	*98·28*	17,526.444	*97·58*	18,844,092	*97·62*	18,520,513	*97·43*	19,217,176	*97·77*

Output of Gondwana coalfields for the years 1919 to 1933—contd.

	1924.		1925.		1926.		1927.		1928.	
	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*	Tons.	*Per cent. of Indian total.*
Bengal, Bihar and Orissa—										
Bokaro . .	1,343,500	*6·34*	1,494,966	*7·15*	1,514,918	*7·21*	1,790,594	*8·11*	2,026,791	*8·99*
Daltonganj . .	4,691	*0·02*	17,274	*0·08*	9,757	*0·05*	..	..	929	*0·01*
Giridih . .	768,690	*3·63*	786,642	*3·76*	818,681	*3·90*	855,253	*3·87*	804,118	*3·57*
Hutar . . .	..	..	..	..	..	..	709	..	205	..
Jainti . .	78,547	*0·38*	76,680	*0·37*	82,604	*0·39*	56,724	*0·26*	48,059	*0·21*
Jharia . .	10,845,642	*51·22*	10,676,883	*51·08*	10,373,736	*49·40*	10,583,487	*47·93*	10,665,479	*47·31*
Karanpura . .	..	..	13,354	*0·07*	123,867	*0·59*	262,014	*1·19*	390,493	*1·73*
Rajmahal Hills .	..	..	1,653	*0·01*	1,788	*0·01*	1,488	*0·01*	636	..
Ramgarh . .	5,905	*0·03*	2,548	*0·01*	585	..	340	..	386	..
Rampur (Raigarh-Hingir).	49,445	*0·23*	45,410	*0·22*	29,272	*0·14*	26,895	*0·12*	31,623	*0·14*
Raniganj . .	6,035,347	*28·51*	5,729,686	*27·42*	6,124,884	*29·17*	6,472,036	*29·31*	6,460,490	*28·66*
Talchir . .	5,417	*50·03*	7,265	*0·04*	13,371	*0·07*	23,316	*0·10*	38,237	*0·17*
Burma—										
Loi-an (Kalaw) .	..	..	..	..	..	..	..	..	..	..
Central India—										
Sohagpur . .	131,174	*0·62*	116,170	*0·55*	108,599	*0·52*	82,541	*0·37*	117,423	*0·52*
Umaria . .	104,124	*0·49*	102,936	*0·49*	108,109	*0·51*	135,120	*0·61*	101,327	*0·45*
Central Provinces—										
Ballarpur . .	127,545	*0·60*	150,490	*0·72*	142,935	*0·68*	158,617	*0·72*	175,872	*0·78*
Hoshangabad .	3	..	..	..	..	..	..	..	..	..
Mohpani . .	76,526	*0·36*	70,039	*0·34*	71,482	*0·34*	..	..	..	..
Pench Valley .	473,896	*2·24*	485,768	*2·30*	416,708	*1·98*	505,913	*2·29*	556,481	*2·47*
Shahpur . .	1.111	..	1,119	*0·01*	423	..	6	..	..	..
Yeotmal . .	..	..	1,138	*0·01*	3,704	*0·02*	2,222	*0·01*	..	..
Hyderabad—										
Sasti . . .	25,050	*0·12*	38,153	*0·18*	28,034	*0·14*	25,477	*0·12*	35,615	*0·16*
Singareni . .	619,725	*2·93*	629,724	*3·01*	609,745	*2·90*	681,736	*3·09*	699,150	*3·10*
TOTAL GONDWANA BEDS.	20,696,338	*97·75*	20,447,898	*97·82*	20,583,202	*98·02*	21,664,488	*98·11*	22,153,314	*98·27*

Output of Gondwana coalfields for the years 1919 to 1933—concld.

—	1929.		1930.		1931.		1932.		1933.	
	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.	Tons.	Per cent. of Indian total.
Bengal, Bihar and Orissa—										
Bokaro . .	2,118,703	9·05	2,160,249	9·07	1,656,597	7·63	1,348,973	6·69	1,304,864	6·60
Daltonganj .	1,522	0·01	1,569	0·01	411	0·00	..	..	..	..
Giridih . .	771,165	3·29	613,533	2·58	713,133	3·28	583,243	2·90	635,924	3·21
Hutar . .	357	0·00	195	0·00	..	..	..	..	..	..
Jainti . .	40,732	0·17	43,580	0·18	50,178	0·23	43,163	0·21	43,530	0·22
Jharia . .	10,785,745	46·05	10,753,858	45·18	9,755,037	44·92	8,551,283	42·43	8,014,949	40·50
Karanpura .	467,127	1·99	482,141	2·02	461,678	2·13	409,566	2·03	343,876	1·74
Rajmahal Hills .	565	0·00	445	0·00	1,699	0·01	1,500	0·01	(a)	0·01
Rampur (Raigarh-Hingir) .	36,774	0·16	37,719	0·16	31,220	0·14	19,498	0·10	22,036	0·11
Raniganj .	6,828,053	29·16	7,218,691	30·33	6,530,713	30·07	6,419,007	31·85	6,265,703	31·66
Talchir . .	47,505	0·20	68,973	0·29	142,312	0·66	253,586	1·26	316,539	1·60
Central India—										
Sohagpur .	92,508	0·39	93.088	0·39	143,607	0·66	166,195	0·82	80,378	0·41
Umaria .	112,624	0·48	100,145	0·42	83,321	0·38	74,293	0·37	172,390	0·87
Central Provinces—										
Ballarpur .	202,061	0·86	211,980	0·89	223,025	1·03	217,421	1·08	256,344	1·29
Korea . .	..	..	3,517	0·01	31,351	0·14	113,858	0·56	264,257	1·34
Pench Valley .	680,270	2·90	740,391	3·11	750,015	3·45	831,817	4·13	978,179	4·94
Raigarh . .	..	..	..	..	..	..	..	..	2,131	0·01
Hyderabad—										
Sasti . .	47,455	0·23	46,808	0·20	53,417	0·25	61,184	0·30	49,794	0·25
Singareni .	768,420	3·28	765.490	3·22	704,158	3·24	593,466	2·95	519,443	2·63
Tandur . .	..	..	..	..	..	..	126,471	0·63	99,718	0·50
Kanala . .	..	..	..	..	..	..	..	..	84,447	0·43
TOTAL GONDWANA BEDS . .	23,001,586	98·12	23,342,372	98·06	21,331,872	98·22	19,814,524	98·32	19,456,254	98·32

(a) Figures not available.

The amounts and particulars of the coal used in India are shown for two years (1922 and 1927) in the following table, and the Indian imports and exports of coal for the period 1914-1933 are given in the table on next page.

Estimated consumption of coal in India during the years 1922 and 1927.

——	Estimated consumption in 1922.	*Per cent. of total.*	Estimated consumption in 1927.	*Per cent. of total.*
	Tons.		Tons.	
Railways . . .	6,186,000(*a*)	*30·8*	(*a*)7,259,000	*33·5*
Admiralty and Royal Indian Marine.	40,000	*0·2*	27,000	*0·1*
Bunker coal . .	796,000	*4·0*	1,317,000	*6·1*
Cotton mills . .	1,131,000	*5·6*	830,000	*3·8*
Jute mills . . .	942,000	*4·7*	935,000	*4·3*
Iron industry (including engineering workshops).	2,415,000	*12·0*	5,260,000	*24·2*
Port Trusts . .	210,000	*1·1*	205,000	*0·9*
Inland steamers . .	582,000	*2·9*	636,000	*2·9*
Brick kilns, potteries, cement works, etc.	437,000	*2·2*	565,000	*2·6*
Tea gardens . .	204,000	*1·0*	223,000	*1·0*
Paper mills . .	147,000	*0·7*	156,000	*0·7*
Collieries and wastage .	2,471,000	*12·3*	2,208,000	*10·2*
Other forms of industrial and domestic consumption.	4,521,000(*b*)	*22·5*	2,085,000	*9·7*
TOTAL .	20,082,000	*100·0*	21,706,000	*100·0*

(*a*) For the official years 1922-23 and 1927-28.

(*b*) This figure appears high, but it includes many classes of establishments and factories which are worked by steam power, such as cotton gins and presses, jute presses, rice and flour mills, dock yards, oil mills, water works, electric power stations, gas works, tramways, gold and other mines, sugar factories, lime kilns, breweries and distilleries, ice and aerated water factories, mints, municipal workshops, woollen mills, chemical works, dye works, rope works, glass works, lac and indigo factories, etc. A certain amount of coke is used for domestic consumption and its use is extending owing to the growing scarcity and increasing cost of wood fuel.

Indian imports and exports[1] of coal during the years 1914 to 1933.

Year.	Imports.	Exports.
	Tons.	Tons.
1914	418,758	579,746
1915	190,654	753,042
1916	34,033	881,741
1917	44,818	408,117
1918	54 346	74,466
1919	48,675	508,537
1920	39,727	1,224,758
1921	1,090,749	275,571
1922	1,220,639	77,111
1923	624,918	136,575
Average 1914-1923	*376,732*	*491,966*
1924	463,716	206,483
1925	483,160	216,090
1926	193,908	617,563
1927	243,603	576,167
1928	210,186	626,343
Average 1924-1928	*318,914*	*448,529*
1929	218,560	726,610
1930	217,029	461,188
1931	88,035	441,249
1932	47,544	519,483
1933	67,330	426,176
Average 1929-1933	*127,700*	*514,941*

[1] Excluding bunker coal and Government stores, but including coke and patent fuel.

From these data it is seen that the annual production of coal during the past dozen years has been under 25 million tons; the coal used for railways is roughly one-third of the whole output; the coal used for the iron and steel industry and workshops is about one-fourth of the whole; the domestic consumption of coal for household purposes is about one-tenth of the total; and the export coal is less than a thirtieth of the annual production. The better grades of coal are used for (1) railways, (2) ironworks, and (3) export; and represent about one-half of the whole output. It may be said that unless there is a considerable industrial expansion, it is difficult to see how any large increase in the use of coal under these three heads can be expected. During the present period of depression, while prices are low, good quality coal is of course being used for almost all purposes.

Indian Coal Problems.

There would be no trouble in the Indian coal trade if every producer could sell his output at a profit. At present the productive capacity of the collieries is far higher than the demand, and prices have fallen to such a low level that several of the companies are faced with the problem of mining cheaply worked coal or closing down their very efficiently worked mines. In nearly every case, except in quarrying or where inefficient pillars are being left, there is very little margin between selling price and cost of working. In such circumstances, the problem is to find a remedy for the depression which has settled on the coal industry, as on others, both in India and elsewhere. Some have hinted that the export trade was lost owing to a lack of control over the quality of the coal sent to over-sea consumers and that this can be recovered; others point out that the State-owned collieries are blocking the trade to a large extent and should be closed; many claim that the reserves of good-quality caking coal are being misused and even wasted and should be subject to control; and several have insisted that the use of coal for household purposes should be further popularised.

It can be shown that the requirements of the consumers of coal in the Indian ocean and in the Pacific ports are probably not ten million tons annually, and that coal from Calcutta has to compete with those from South Africa, Australia, Japan and other countries. It is doubtful if the Indian exporter can ever hope to acquire more than

an equal share of this trade; an equal share would be one-fifth of the whole or, say, two million tons. This is a valuable outlet for some companies, and to assist in recovering the export trade the Government of India appointed a Coal Committee under the chairmanship of Sir Frank Noyce to go into the matter in 1925. Their enquiries are discussed in the next section.

Indian Coal Committee of 1925.

This committee was appointed by the Governor General in Council, under the Department of Commerce, Resolution No. 47-T. (5), dated the 20th September, 1924, and they issued their report on the 28th March, 1925. The committee were to enquire and report

'(1) generally what measures can be taken by Government, by the coal trade, by the railways and by the ports, whether singly or in combination, to stimulate the export of suitable coal from Calcutta to Indian and foreign ports; and

(2) in particular, whether effective measures can be taken for pooling and grading of Indian coal for export and for bunkering, and how the cost of such measures should be met.'

The Indian Coal Committee (1925) made a full investigation into the whole subject of the export trade and after discussing (1) the comparative merits and prices of Indian and other coals; (2) the possibility of economies in the coalfields; (3) the transport of coal by rail; (4) railway freights, terminals and rebates; (5) assistance by and co-operation between collieries and railways; (6) the working of the Calcutta docks and coal depots; (7) steamer freights; (8) the establishment of a grading board, and (9) the impracticability of pooling in India, they concluded as follows:—
'The railways and Port Commissioners can render most valuable assistance by reducing their charges, by speeding up transport and by facilitating the loading of coal in proper condition, but the main effort must come from the "coal trade itself"...........'

Coal Grading Board.

One of the important recommendations of the Indian Coal Committee (1925) was that a grading board should be appointed, whose duties would be to grade the various seams and arrange for the

issue of certificates for each consignment of coal exported. The general outline was given for classifying all Indian coals, and it was suggested that a grading list should be published by the grading board as soon as possible, classifying the different collieries and seams on this system. Only those collieries included in the grading list would be eligible for the special concessions from the Railways and from the Calcutta Port Commissioners, and only certified coal from those collieries would be given the above concessions. Act No. XXXI of 1925 was passed by the Indian Legislature and received the assent of the Governor General on the 23rd September, 1925.

For the information of overseas buyers, the following particulars regarding the Indian coalfields and the procedure adopted in granting 'grade' and 'shipment' certificates will be of interest:—The only coalfields at present of importance to overseas buyers are those usually designated as the Bengal or Damodar Valley coalfields, which include the collieries in Bengal and Bihar and Orissa. The whole of the coal raised in Bengal comes from the Raniganj coalfield, 130 miles west-north-west of Calcutta. The Jharia coalfield, another 30 miles in the same direction, lies wholly in Bihar and supplies 75 per cent. of the coal from the province of Bihar and Orissa. The above two coalfields produce 75 per cent. of the total Indian output of coal and all the coal exported at present comes from these two fields. The most important seams in the Raniganj field are the Dishergarh, Poniati, Sanctoria, also the Ghusick, Koithi, Chanch, Salanpur A, Samla, Kajora and Jambad. In the Jharia field, the best known seams of good quality are Nos. XIII, XIV, XIV-A., XV, XVII and XVIII. Seams Nos. X, XI, XII also contain good coal.

The grades fixed by the Board are as follows:—

Low volatile.	*High volatile.*
Selected grade.—Up to 13 % ash and over 7,000 calories or 12,600 B. T. U's.	Up to 11% ash; over 6,800 calories or 12,240 B. T. U's. and under 6% moisture.
Grade No. 1.—Up to 15 % ash and over 6,500 calories or 11,700 B. T. U's.	Up to 13% ash; over 6,300 calories or 11,340 B. T. U's. and under 9% moisture.
Grade No. 2.—Up to 18% ash and over 6,000 calories or 10,800 B. T. U's.	Up to 16% ash; over 6,000 calories or 10,800 B. T. U's. and under 10% moisture.

Grade No. 3.—All coals inferior to above.

The office of the Coal Grading Board is in the Secretariat Buildings, 1, Council House Street, Calcutta.

State-owned Collieries.

Of the seven to eight million tons of coal used by the Railways and other Government purposes, the raisings from the State Collieries do not exceed three million tons. The remainder is purchased on Government account from private companies by the Chief Mining Engineer, Railway Board. However, three million tons is a large amount of coal to be barred from competitive trade, and it is a question whether private vendors could not at the same price produce coal as cheaply and of the same quality as that from, say, the quarries in the Bokaro and Karanpura coalfields. It is possible that the cost of production at Giridih could be proved high at present prices, but it is doubtful if that coalfield could be more efficiently worked for the relatively high percentage of coal extracted—as already shown—except under State management during periods of bad trade. In the light of what is known to be taking place in other coalfields it would be inadvisable either to hand the Giridih collieries over to private firms or to close them down. In view of the fact that most of the Railways in India are State-owned, it would be unbusinesslike if the State owned no collieries, especially such easily worked ones as in Bokaro; but, on the other hand, seeing that purchases by the Railways fix the price of all coal caution is required in accepting very low tenders for good coal. For example a large producer-consumer may, by tendering his good coal at a low price, so lower the market price that he can purchase all his requirements at the same price although he could not obtain the same quantity from his own collieries at that price.

Electrification of Railways.

The fact that good-quality and perhaps good caking coal, including exported coal, is used for steam raising, both by State Railways and by other consumers, is not difficult to understand. Nor can it be easily avoided, because there are few better coals for this purpose—consequently it is not altogether a misuse of such coals, although should the opportunity offer they could be used for more suitable purposes. The use of inferior coals or of coals which do not give out the same heat will lead to a larger consumption of the poorer coals and would probably lead to enhanced expenditure rather than to economy. The real solution in this connexion

would appear to be the electrification of all railways converging on Calcutta, from distances of 200 to 250 miles from this city. Such a project would, of necessity, involve the erection of several central electrical stations at suitable places in the coalfields and along the railways. From these the electrical energy, cheaply obtained by the use of inferior grades of coal burnt in pulverised form, could be supplied to a large industrial area, with its ironworks, mines and workshops, as well as to several large towns. The cost per unit of such electricity would perhaps not greatly exceed one-fourth of an anna, but against this cheap electricity must be placed the vast capital expense involved in the alterations. Even if spread over a decade, the benefits would not be felt for several years. That this will come is certain; the question is when?

Enforcement of Sand-Stowing.

It is universally agreed that sand-stowing, or some similar method of hydraulically packing the goaf in coal mines, would reduce subsidence, eliminate underground fires, and allow of the almost complete extraction of the seam worked. That sand-stowing cannot be undertaken, during a period of depression long continued, is proved by the fact that well-equipped collieries in the Raniganj, Jharia, Mohpani, Ballalpur and Singareni coalfields which had used sand-stowing, have now been forced to discontinue it. The price at which coal has to be sold does not allow the requisite margin. In some cases collieries have closed down, rather than work without this efficient means of safety and far-sighted economy. There have been several papers and discussions on the subject in the *Transactions of the Mining and Geological Institute of India*—Ballalpur, X, p. 52, (1915); Mohpani, XI, p. 29, (1916); Ramnagar, XIV, p. 108, (1920) and XV, p. 60, (1921); Jharia, XV, p. 107, (1921) and XXIII, p. 188, (1929) and XXVI, p. 69, (1931).

Thus the question of cost is the governing factor, especially where the sand has to be stowed in old galleries for depillaring operations. It is estimated that, in working a virgin seam, the removal of one ton of coal requires the deposit of one and a third tons of sand. In the case of depillaring, it is possible that the sand may be as much as three tons per ton of coal taken. It is not too

much to say that in the Jharia, as well as in the Raniganj fields today, it is for depillaring that the need for sand-stowing is most pressing. Now, it has been suggested that the extra expense of stowing might be met by a rebate on railway freight, but this will mean a loss in railway earnings to an extent possibly of 50 lakhs of rupees; and no such fall in revenue can be considered at present. There the matter stands, except that the advantages of removing sand from the Damodar river in this area will relieve silting lower down and may include those of reducing the likelihood of this river changing its course and thus spoiling valuable land in the Burdwan district. But it is unlikely that the Irrigation Department will be so convinced of this necessity as to give 40 to 50 lakhs a year towards expenses for sand-stowing, in the collieries of the Raniganj and Jharia coalfields. The only remedy is to fix a minimum price for good coals and enforce sand-stowing in all mines working such seams.

Conservation of Caking Coal.

If we were all fully agreed as to what a metallurgical coke really is, it would be possible to specify correctly the kind of coal necessary for its preparation. At present the definition is far from satisfactory, and so any coal which yields a hard silvery porous cake is considered a caking coal, provided the ash percentage of the coke is under 21 per cent. It is known that a hard coke may, by one method of treatment, be obtained from a coal which has an unsatisfactory result by another. A fine slack, a narrow oven chamber, high and sudden temperatures, ramming of the charge, or even a little sprinkling with water before charging, have been found necessary to produce a good coke from coals which otherwise appeared unattractive. In short, much more research is necessary before we can speak with confidence as to the caking value of different coals. In the case of coal with under 16 per cent. ash and less than 4 per cent. of moisture and a volatile percentage between 22 and 30, there is always hope that such a material can be made to yield a hard coke. Sometimes, as the workings get deeper, *i.e.*, below the zone of weathering, the coal is found to pass into a natural caking variety; and this property may often be improved by picking out dull coal bands. When the moisture percentage is higher than five a hard coke is rarely obtained except with brightly banded

(vitrain) coal. As a rule, there is a better chance of getting a coke from a coal with 20 per cent. ash, if the moisture is low, than with a coal of 10 per cent. moisture, although the ash is low.[1]

According to the estimates of good quality caking coal, and on the basis of four million tons ($2\frac{1}{2}$ million tons of coke) a year, the reserves should last nearly 400 years. If the extraction from the mines is 50 per cent., the life of the supplies will fall to 200 years, for metallurgical purposes only. But using this coal as at present, with the same allowance for extraction, it is calculated that the supplies will be nearing exhaustion after 40 years. Generally too much stress is laid on this point, but too little in the case of the Jharia coalfield which is the present main store house of supply. It is certain that the supplies of caking coal from this field—estimated at 900 million tons—will have been entirely exhausted or rendered unavailable long before the 40 years has expired, if the existing methods of working in that field cannot be improved upon. It is difficult to see how this is to be effected without sand-stowing unless the whole field is closed down, pending a revival of trade and better prices.

Coal for Household Use.

The percentage of the annual production of coal in India, used for domestic (household) purposes, is about one-tenth. This, for a population of 360 millions, works out to the trifling figure of 14 lbs. per head per year. It is in this direction—the popularisation of coal in the form of semi- or soft-coke, as a smokeless household fuel—that there appears to be a possibility for a considerable expansion in trade. If even one million people used one ton of coal each (as soft-coke) a month, there would be an increase from 2 to 12 million tons. The extra 10 million tons would cover twice over the whole of the export coal and the raisings from State Railway collieries. Moreover the smoke nuisance in towns in the winter months would be abated and thus lead to cleaner and healthier conditions. And those who see in the use of soft coke a saving of cowdung (still widely used for fuel) will say that the yield of the fields will be improved by substituting coal for cowdung as fuel and placing the latter on the fields as manure.

[1] *Mem. Geol. Surv. Ind.*, LVI, pp. 180-182, (1930).

Soft Coke.

Although the present production of soft coke in India does not exceed 700,000 tons annually and is almost entirely used in the larger towns of Bengal and Bihar, there are attractive features in this trade. The production of soft coke during the years 1921 to 1933 is given later (page 363). Soft coke manufacture has been described in 'Capital' (July 5th and 12th, 1928). It is there shown that only the relatively inferior grades of coal are used for this purpose and that probably 100 tons of raw coal produce 50 tons of soft coke. It has already been pointed out that there is a possibility for great expansion in the coal industry by the popularisation of soft coke as a domestic fuel. With a view to assist this branch of the coal industry, the following Act of the Indian Legislature received the assent of the Governor-General on the 1st October, 1929:—

Act No. VIII of 1929.—*An Act to provide for the levy of a cess on soft coke despatched by rail from collieries in the provinces of Bengal and Bihar and Orissa.*

1. (1) This Act may be called the Indian Soft Coke Cess Act, 1929....................

2. (c) 'Soft-coke' means all coke which is unsuitable for metallurgical purposes.

3. (1) There shall be levied and collected on all soft coke despatched by rail from collieries in the provinces of Bengal and Bihar and Orissa a cess at the rate of two annas per ton.

Methods of Mining Coal.

It has been said that the best thickness desirable for a coal seam in India is about seven feet, as women can then carry baskets on their heads without brushing the roof timbers. However, it is true that most of the seams worked are not less than six feet, and often as much as 20 feet or more in underground galleries. Notification No. M-1055, dated the 7th March, 1929, of the Government of India, Department of Industries and Labour, concerns regulations for prohibiting the employment of women underground so that gradually fewer shall be employed, until after the 1st July, 1939, no women shall be permitted in the underground workings of mines without the special sanction of the Chief Inspector of Mines.

Production of Soft Coke in India during the years 1924 to 1933 (long tons).

—	1924.	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1933.
Assam— Lakhimpur	..	..	..	..	..	..	..	..	..	..
Bengal— Raniganj	7,521	7,471	7,941	11,596	18,736	17,498	13,491	16,875	18,904	18,414
Bihar and Orissa— Santal Parganas	(*a*) 3	(*b*) 164	(*a*) 515	..	..	..	..	..	(*a*) 46	..
Raniganj (*c*)	115,442	113,173	104,704	92,633	60,186	42,636	42,489	26,764	17,908	18,158
Jharia	176,797	290,807	397,589	500,812	606,520	693,186	688,250	676,976	719,980	784,429
Bokaro	4,882	4,328	4,916	3,571	3,560	4,407	5,391	3,544	3,390	3,164
Giridih	..	26	..	..	..	..	..	..	..	..
Karanpura	..	..	..	..	..	..	..	17	..	..
Central Provinces— Pench Valley	100	..	..	..	..	..	..	..	..	..

(*a*) Raniganj coalfield. (*b*) Rajmahal (Damin-i-ko) coalfield. (*c*) Manbhum district only.

The normal method of mining the gently inclined, relatively thick seams of coal in the Raniganj, Jharia and other coalfields, is usually some modification of the South Staffordshire 'Square Work' form of pillar and stall. Descriptions of such workings are given in many papers in the *Transactions of the Mining and Geological Institute of India*[1] and in other publications. And, as in South Staffordshire, the outbreak and fighting of gob fires has also to be faced in Indian collieries. It is agreed now by most mining engineers that such fires are due to the crushing of the coal pillars, so that oxidation and heating of the finer material leads to fire in positions where the ventilation is bad.

The crushing strength of coal pillars has received detailed attention[2] but, when it is remembered that the Barakar seams were probably overlain by over 12,000 feet of strata giving a weight per square foot of 450 tons, or say 7,000 lbs. per square inch, it is clear that the coal should stand any weight that could possibly come on them now in fair-sized pillars. Unfortunately, the side coal crushes readily if the pillars are small, owing to want of lateral support from the material, which has been removed from the galleries around the pillars. The losses resulting from fires, etc., include the coal in the crushed pillars and the areas involved in the resulting subsidences. This has been dealt with in two valuable papers.[3] I quote from the last reference (page 388).

'Experience has shown that when the outcrop of a thick seam of coal has been quarried it is expedient that a solid barrier of coal be left between the quarry and any underground workings which may subsequently be made to the dip.......In one instance a fire commencing in one mine eventually involved four other mines, and in five other cases a fire occurring in one mine spread to adjacent mines.'

'If proper precautions had been taken the loss of coal by fires and collapses in the Raniganj and Jharia coalfields would probably not have been more than one-tenth of what it has actually been.'

According to Mr. N. Barraclough the total coal taken from the Jharia coalfield was about 210 million tons, and the coal standing in pillars were nearly 132 million tons, while the coal lost by fires and collapses were roughly 16 million tons. In short, the getting of 210 million tons has meant the entire loss of 16 million tons, and led to another 132 million tons being left as pillars, which, it seems,

[1] *See* Vols. II, III, VI, VII, IX, XII, XIV, XV, XXIII and XXV.

[2] *Trans. Min. Geol. Inst.*, XXV, p. 325, (1931); *see also Mem. Geol. Surv. Ind.*, VII, p. 55, (1931).

[3] *Rec. Geol. Surv. Ind.*, LXII, pp. 377-389, (1929).

may prove dangerous to extract. This proportion of 210 to 148, a loss of 41 per cent., comes very near to the rough estimate made by Mr. R. G. M. Bathgate[1] that the loss may be anything between 50 and 75 per cent.

From these statements and the data already given of the total reserves of a coalfield, as compared with the reserves in a given seam of good quality coal in that field, it appears that, with the existing methods of working thick coal seams in India, the total quantity extracted is rarely more than half that originally present in the seam. It is thus a mere fraction of the total coal in the seams of the coalfield. The percentage is favourably improved when two or more seams can be worked: as they are worked in the Raniganj and Jharia coalfields. In these coalfields the gentle dip of the seams often permits of depillaring operations in the seam above while development is in progress in the seam below. Thus it is that depillaring operations are usually not under each other in the same mine.

In the Jharia coalfield, where two seams of good quality underlie each other with a few feet of stone parting between, it is imperative that at least the pillars and galleries should have strict verticality as in the walls and rooms of double storied houses. Yet this simple precaution, which has not always been taken, is obvious, and failure to follow it has led not only to serious collapses, but to loss of life and property. In the case of steeply inclined thick seams of coal, such as those in the south-east of the Jharia coalfield, the danger from fires appears to be greater than elsewhere. This is ascribed partly to the sheared condition of the strata (the coal) and also to lack of foresight in mining—in mining the outcrop instead of working below ground.

With so many evidences of a poor recovery of coal over wide areas, it would follow that a general effort must be made to discover a remedy so as to work the seams efficiently, both in regard to cost of mining and high percentage of extraction. As already stated it is the general opinion that this remedy is to hand in the form of sand-stowing for the latter, but the present selling price of coal does not permit of the use of this remedy. The question thus arises that if the cost of coal is too low, which it is, how will it be best to improve it without serious injury to consumers. This seems at first impos-

[1] *Trans Min.. Geol. Inst., Ind.*, XII, p. 13, (1918).

sible because it is essential that the price of coal must be raised —it is too cheap.

At the present time the price of good quality coal is largely fixed by the tenders for supplies to the Chief Mining Engineer, Railway Board, for the consumption of the State Railways. Now it may happen, and has happened, that a large buyer of coal who also possesses a small colliery working a good seam may tender to the Chief Mining Engineer at a very low figure. By so doing the market price of the same quality coal is more or less fixed and the same vendor can then, as a buyer, obtain supplies for his own use at a far lower figure than might otherwise have been possible. This does not seem to be helpful to the real coal vendors and is harmful to the coal industry.

It would seem, seeing that the State Railways are the biggest purchasers of coal and also possess collieries of their own, that the most reasonable method of purchase on State account, during the present depression, should be at a price averaged out from the cost of working in the State mines. Thus if the average overall cost of obtaining good quality coal in the State-owned collieries was say Rs. 5-8 this should be the minimum price of coal of the same quality in the open market. The prices should be fixed, and any underselling between vendors in regard to other contracts should be regarded as a breach of contract with Government.

It is true that a heavy loss would have to be faced by the railways on their purchases of coal, but then they need not give freight concessions for the transport of coal during such periods. The enhanced prices would improve the coal trade; the enhanced freights would to a considerable extent balance earnings; and it is a question whether the earnings would not exceed the loss in purchase prices. It is in any case certain that the coal trade would be more active, and permit of the adoption of sand-stowing and better methods of working.

There is also another important point. This is that no colliery or other company is in any way encouraged to experiment with the problem of the hydrogenation of coal or the manufacture of benzine and similar by-products. At present they immediately become subject to a tax on any benzine that they extracted from coal. It seems to me the tax on benzine is due to an oversight masked by its market association with petrol. The matter if investigated would I am sure lead to the removal of the tax and thus give a

great help towards this very important subject of extracting benzine and other byproducts from coal. These researches could best be done now while the price of coal is low, and would assist in the recovery and rejuvenation of the coal industry in India.

State Ownership of Mineral Rights.

On a strict geological definition, *coal* is regarded as a *rock* and not as a mineral[1] but in the Mining Rules regulating the grant of exploring and prospecting licences and mining leases in India, coal is regarded as a major mineral. As these rules apply only to lands, the mineral rights of which are vested in the Government, it is necessary for the prospector or miner to be sure that he is dependent on the mining rules and not upon the common law rights.

'Unfortunately, from the point of view of mineral development, it is by no means clear what land falls in either category; the view previously taken by the administration not appearing to be entirely reconcilable with the more recent decisions of the Privy Council.'

The above extract is made from the brochure of the Imperial Mineral Resources Bureau, dealing with The Mining Laws of the British Empire and of Foreign Countries (Vol. VI), British India, Part 1, General Principles, Major Minerals, 1924, by Gilbert Stone. And on page 2 it is stated:—

'The question relating to the right of the State to the minerals in land in India was considered by the Government of Madras, the Government of India and the Imperial Government in a series of communications which passed between the years 1877 and 1880......and definite conclusions expressed......ever since the conclusions were arrived at they have formed the basis of the State policy in relation to mineral development, the exercise of State rights in respect of minerals, and in the acquisition of land for public purposes, these conclusions have much practical weight unless and until disapproved by the Judicial Committee.'

And continuing it is stated that (page 2):

'The fact that as a matter of policy the State has not in the past claimed any right to the minerals in the permanently-settled estates would not *per se* appear to affect the legal position. As the Privy Council observed in the case of Durga Prasad Singh *v.* Braja Nath Bose, (1912) Law Report 39 Indian Appeal 141, the rights of the Government are not affected by the fact that numerous cases have been brought by *zamindars* claiming, and successfully claiming, mineral rights in the Government has not been a party to such suits.'

[1] *Mem. Geol. Surv. Ind.*, LVII, p. 67, (1931).

And on page 4 the following occurs:—

'It was established as an administrative principle by the correspondence referred to that, except in permanently-settled estates, it is presumed throughout India that, in the absence of any distinct judicial precedent or proof of established usage, the State has a right to minerals.'

Page 5:—

'As a matter of law, however, it should be noted that in Shashi Bhusan Misra *v.* Jyoti Prasad Singh Deo, (1916) Law Report 44 Indian Appeal 46; 44 Calc. 585, the Privy Council observed at p. 591, "By the Permanent Settlement of 1793 all the mineral rights were confirmed to the *zamindars*. If such rights were already possessed and recognised at the date of the settlement, this confirmation would hardly have been needed, and this suggests, up to that date, the rights recognised and granted in the lands were not considered as including the minerals; if this were so, as the grant in question could have created no rights in the property which the grantor did not possess, no right to the minerals could have been conferred."

'The claim of the State to ownership in the minerals in permanently-settled estates in the Presidency of Bengal has been asserted in the case of Secretary of State *v.* Raja Jyoti Prasad Sinha at present pending on appeal to the Privy Council.'

And page 6:—

'Granted that the minerals are in the State it would appear that the rights to them vests in H. M.'s Secretary of State for India, and thus property in them appertains neither to a Local Government nor to any particular department. Mineral rights are ordinarily administered by the Local Government of the Province in which the minerals are situated subject to statute or to any rules made or sanctioned by the Government of India and to the general executive control of the Supreme Government (*See* G. O. I. Financial Department Resolution 295 A, dated 19th January, 1920).'

CHAPTER 19.

STATISTICAL INFORMATION : THE PRODUCTION OF COAL IN INDIA.

Total Production.

In the Quinquennial Reviews of the Mineral Production of India published in the *Records of the Geological Survey of India* since 1898, the total coal from all the coalfields is classified according to its geological age. Two main divisions are employed—Gondwana coalfields and Tertiary coalfields. The former could, and is being, more strictly classed as Lower Gondwana coalfields, which are entirely of Palæozoic (Permian) age. The latter are now termed Mesozoic and Tertiary coalfields as they have included Cretaceous (or what were believed to be such) coals. From the Statistics on Indian coal production[1] it will be seen that the production from the Lower Gondwana coalfields has averaged about 98 per cent. of the total Indian production, while the Mesozoic and Tertiary coalfields produce the remaining 2 per cent. This proportion can be taken as more or less consistently maintained for all purposes of calculation. On page 352 of the present memoir, the proportion is 98·32 for the Lower Gondwana fields.

In 1878, the total Indian output of coal was barely one million (1,015,210) tons; in 1888, the production was nearly 1¾ million (1,708,903) tons; in 1898, it had risen to over four and a half million (4,608,196) tons; in 1908, the total was a little over 12¾ million (12,769,635) tons; in 1918, almost 20¾ million (20,722,493) tons; and in 1928 it was over 22½ million (22,542,872) tons. These particulars are fully shown in the accompanying tables for the periods 1878 to 1903 and 1904 to 1932 given on pages 370 to 373. It must be pointed out, however, that changes in the political divisions of Assam, Bengal, Bihar, the Central Provinces and Orissa have led to some confusion in the records of coal production from each province.

[1] *See Rec. Geol. Surv. Ind.*, LXIV, pp. 14-15, (1930).

Quantity, in tons, of Coal produced in each province

Year.	Burma.	Assam.	Bengal.	Rajputana.	Central India.	Punjab.
1878 .	..	..	957,243	..	..	..
1879 .	..	..	891,047	..	..	..
1880 .	..	..	988,565	..	..	..
1881 .	..	..	930,203	..	..	..
1882 .	..	..	1,038,872	..	..	..
1883 .	..	..	1,200,957	..	..	..
1884 .	..	16,493	1,257,392	..	2,100	..
1885 .	..	43,707	1,123,700	..	7,698	..
1886 .	..	70,859	1,186,802	..	13,539	..
1887 .	..	89,302	1,310,090	..	15,497	7,523
1888 .	..	101,528	1,380,594	..	41,580	11,249
1889 .	..	116,676	1,541,356	..	52,956	22,835
1890 .	..	145,708	1,626,245	..	77,842	40,677
1891 .	..	154,208	1,747,122	..	69,741	60,714
1892 .	3,670	164,050	1,920,052	..	88,623	66,352
1893 .	9,038	164,420	1,902,866	..	94,348	77,294
1894 .	12,111	169,448	2,035,934	..	132,837	66,467
1895 .	17,289	172,717	2,716,155	..	118,479	72,493
1896† .	22,093	177,259	3,037,920	..	115,386	79,017
1897 .	11,472	185,533	3,142,497	..	124,778	92,792
1898 .	6,975	200,329	3,622,090	511	134,726	85,862
1899 .	8,105	225,623	4,035,265	4,249	164,569	81,835
1900 .	10,228	216,736	4,978,492	9,250	164,489	74,083
1901 .	12,466	254,100	5,487,585	12,094	164,362	67,730
1902 .	13,302	221,096	6,259,236	16,503	171,538	55,373
1903 .	9,306	239,328	6,361,212	21,764	193,277	43,704

* Financial and Commercial Statistics of British India,

† Also 1,000 tons

*in India, during the years 1878 to 1903.**

Kashmir.	Baluchistan.	Central Provinces.	Nizam's Dominions.	Madras.	TOTAL.	Year.
..	..	57,967	..	..	1,015,210	1878.
..	..	33,515	..	..	924,562	1879.
..	..	31,228	..	..	1,019,793	1880.
..	..	67,527	..	..	997,730	1881.
..	..	91,370	..	..	1,130,242	1882.
	..	115,019	..	..	1,315,976	1883.
.	..	121,833	..	..	1,397,818	1884.
	..	119,116	..	..	1,294,221	1885.
..	..	117,287	..	..	1,388,487	1886.
.	411	128,981	3,259	..	1,564,063	1887.
.	2,802	157,768	13,382	..	1,708,903	1888.
	8,238	144,465	59,646	..	1,946,172	1889.
	15,541	137,022	125,486	..	2,168,521	1890.
	10,368	141,736	144,668	20	2,328,577	1891.
..	13,284	132,005	149,601	61	2,537,696	1892.
..	20,094	135,118	157,421	502	2,562,001	1893.
.	24,753	140,495	240,525	1,337	2,823,907	1894.
..	25,458	122,776	292,915	1,737	3,540,019	1895.
..	26,257	141,185	262,681	..	3,863,698	1896.
..	12,043	131,629	365,550	..	4,066,294	1897.
..	13,372	149,709	394,622	..	4,608,196	1898.
..	15,822	156,576	401,216	..	5,093,260	1899.
..	23,281	172,842	469,291	..	6,118,692	1900.
..	24,656	191,516	421,218	..	6,635,727	1901.
1,060	33,889	196,981	455,424	..	7,424,402	1902.
999	46,909	159,154	362,733	..	7,438,386	1903.

11th issue, p. 371, Table XXVI, Coal Mines, (1904).
from the United Provinces in 1896.

Quantity, in tons, of Coal produced in each Province

Year	Burma.	Assam.	Bengal[1].	Bihar.	Rajputana.	Central India.	Punjab.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1904 .	1,105	266,765	3,350,257	3,713,423	45,078	185,774	45,594
1905 .	..	277,065	3,202,536	3,971,567	42,964	157,701	62,622
1906 .	1,222	285,490	3,650,563	4,967,257	32,372	170,292	73,119
1907 .	..	295,795	3,981,659	6,011,689	28,062	178,588	60,749
1908 .	..	275,224	4,221,781	7,338,130	21,297	155,107	54,794
1909 .	..	305,563	4,034,812	6,625,999	11,449	121,496	37,208
1910 .	..	297,236	4,212,606	6,564,094	12,744	130,400	49,189
1911 .	..	294,893	4,311,956	7,151,279	14,761	143,558	30,575
1912 .	..	297,160	4,944,268	8,466,932	18,251	149,921	38,409
1913 .	..	270,862	5,327,381	9,507,356	18,781	148,978	51,040
1914 .	..	305,160	4,946,312	10,078,424	17,211	152,906	54,303
1915 .	25	311,296	5,484,596	10,150,194	17,796	139,680	57,911
1916 .	..	287,315	5,535,307	10,165,015	13,841	200,285	47,449
1917 .	..	301,480	5,376,022	11,135,076	6,045	198,407	49,869
1918 .	..	294,484	6,368,519	12,562,768	11,334	199,975	50,418
1919 .	1,500	291,734	6,815,126	14,036,744	14,760	182,141	46,893
1920 .	..	325,585	4,907,679	11,148,442	18,216	158,051	58,078
1921 .	300	312,465	5,211,855	11,960,991	24,521	192,034	67,242
1922 .	172	348,103	5,203,214	11,768,482	15,055	161,231	67,180
1923 .	1,271	326,149	5,557,424	12,220,792	7,119	175,950	63,501
1924 .	255	334,842	6,035,347	13,046,075	21,870	235,298	80,422
1925 .	25	318,842	5,729,086	13,070,000	28,153	219,106	74,662
1926 .	..	301,061	6,124,884	12,925,936	31,275	216,708	68,048
1927 .	..	323,342	6,472,036	13,550,609	17,858	217,661	62,704
1928 .	..	308,089	6,460,490	13,937,096	27,386	218,750	46,152
1929 .	..	322,515	6,828,053	14,185,916	35,275	205,132	43,136
1930 .	..	359,040	7,218,691	14,055,670	35,123	193,233	50,619
1931 .	..	275,021	6,530,713	12,638,733	38,148	226,928	54,840
1932 .	..	210,035	6,419,007	10,937,728	37,043	240,488	72,857
1933 .	..	194,154	5,691,189	10,917,657	33,194	252,768	94,099

[1] Includes the output of the whole of the Raniganj coalfield lying in

in India during the years 1904 to 1933.

Kashmir.	Baluchistan.	Central Provinces.	Hyderabad (Nizam's Dominions).	Orissa.	N. W. F. Province.	TOTAL.	Year.
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	
270	49,867	139,027	419,546	..	..	8,216,706	1904.
..	41,725	147,265	454,294	..	..	8,417,739	1905.
..	42,164	92,848	467,923	..	..	9,783,250	1906.
..	42,488	134,088	414,221	..	..	11,147,339	1907.
..	45,212	213,789	444,211	..	90	12,769,635	1908.
..	52,449	238,100	442,892	..	96	11,870,064	1909.
..	52,614	200,437	506,173	830	90	12,047,413	1910.
..	45,707	211,616	505,380	5,669	140	12,715,534	1911.
..	54,386	233,996	481,652	21,314	50	14,706,339	1912.
..	52,932	235,651	552,133	42,805	90	16,208,009	1913.
..	48,234	244,745	555,991	60,883	94	16,464,263	1914.
..	43,607	253,118	586,824	58,825	60	17,103,932	1915.
..	42,163	287,832	615,290	59,737	75	17,254,309	1916.
..	40,785	371,498	680,629	52,892	215	18,212,918	1917.
..	43,125	48[illegible],470	659,122	51,038	240	20,722,493	1918.
..	34,328	497,021	662,196	45,574	20	22,628,037	1919.
..	33,941	491,205	694,080	36,987	..	17,962,214	1920.
..	54,627	712,914	688,721	77,277	..	19,302,947	1921.
..	60,135	675,916	642,880	68,618	..	19,010,986	1922.
..	42,562	548,074	658,429	55,612	..	19,656,883	1923.
..	40,557	679,081	644,775	54,862	..	21,174,284	1924.
..	34,797	708,554	667,877	52,675	..	20,904,377	1925.
..	15,586	635,252	637,779	42,643	..	20,999,167	1926.
..	14,444	666,758	707,213	50,211	..	22,082,336	1927.
..	17,931	732,353	734,765	69,860	..	22,542,872	1928.
..	16,222	882,331	815,875	84,279	..	23,418,734	1929.
..	15,894	955,888	812,298	106,692	..	23,803,048	1930.
..	16,554	1,004,391	757,575	173,532	..	21,716,435	1931.
..	18,928	1,163,096	781,121	273,084	..	20,153,387	1932.
...	11,462	1 500,911	758,402	338,575	..	19,789,163	1933.

Bihar and Bengal and that of the Darjeeling district.

Total Gondwana Coal raised in India.

The following figures are as near an approximation to the present political limits of the Provinces and States of India which the available information permits. The production is the total output since the coalfields were opened to the time operations were suspended, or the collieries abandoned, or to 1933, according to each case. These data do not in any way refer to tonnages lost, or involved in the mines from which the raisings were made. This question of percentage extraction is dealt with specially on pages 346 to 349 of this memoir. The actual coal obtained from the coal seams and brought to the surface is the amount specified under the term production given below :—

Total production of coal by Province.

Province or State.	Period.	Production.
Bengal	1774 to 1933	213·69 million tons.
Bihar	1842 to 1933	339·20 „
Central Provinces	1874 to 1933	18·66 „
Hyderabad	1887 to 1933	22·76 „
Madras	1891 to 1895	trifling.
Orissa	1913 to 1933	1·82 million tons.
Rewah State	1884 to 1933	7·30 „
	Total to 1933	603·43 „

Coal raised in each Province.

Bengal.

As now constituted, the coalfields in Bengal are those of the Darjeeling district and that part of the Raniganj coalfield in the Bankura, Burdwan and Birbhum districts, *i.e.*, the areas largely east of the Barakar river and Panchet Hill, and south and east of the Adjai river from about north of Asansol. West of the Barakar river and with Panchet Hill, the area is in the Manbhum district of Bihar. North of the Adjai river, the field is largely

in the Santal Parganas. However, it is now usual to consider the Raniganj coalfield as a single area and to give the production of the field as a whole; but separate returns for each district area have been kept in past years and are still so received. The complications begin with the inclusion of Assam as well as Bihar and Orissa as part of Bengal in earlier years: and the inclusion of some of the Raniganj production figures for coal with those of the Rajmahal hills, under the heading Santal Parganas.

It is simplest to treat the coalfields of Bengal as simply those of Raniganj (as a whole) and the Darjeeling district. The total coal raised in these two areas is given below :–

Total coal raised in Bengal.

Field.	Period of output.	Production.
Raniganj	1774 to 1933	214 million tons.
Darjeeling	1896 to 1900*	7,250 tons.
	Total output Bengal about	208 million tons.

* Operations unsuccessful.

Bihar.

In this province are included the coalfields of the Rajmahal Hills, Deogarh (Jainti), Giridih (Karharbari), Jharia, Bokaro, Ramgarh, Karanpura and Palamau (Hutar and Daltonganj). The production from these fields is shown below :–

Total coal raised in Bihar.

Field.	Period of output.	Production.
Rajmahal Hills	1858 to 1933*	100,000 tons.
Deogarh (Jainti)	1915 to 1933	1,543,000 ,,
Giridih (Karharbari)	1850 to 1933	46,000,000 ,,
Jharia	1897 to 1933	268,000,000 ,,
Bokaro (East)	1909 to 1933	23,452,162 ,,
Ramgarh	1920 to 1928*	25,389 ,,
Karanpura (South)	1925 to 1933	2,872,916 ,,
Hutar	1927 to 1930*	1,466 ,,
Daltonganj	1842 to 1931*	2,000,000 ,,
	Total output Bihar about	338¼ million tons.

* Stopped producing.

Central India (Rewah).

All the Lower Gondwana coalfields of this Agency are in Rewah State. The coalfields lie in the Son valley and include Singrauli, Umaria, Johilla and Sohagpur. The production of coal from the Rewah territories is given below :—

Total coal raised in Central India.

Field.	Period of output.	Production.
Umaria	1884 to 1933	6,020,989 tons.
Johilla	1898 to 1902*	Included in Umaria.
Sohagpur	1921 to 1933	1,291,581 tons.
	Total output Rewah State about	7½ million tons.

* Not worked since.

Central Provinces.

In this province lie the coalfields of Sirguja and Chhattisgarh (Kurasia), the Satpura basin (Mohpani and the Pench Valley) and the Wardha Valley in Chanda and Yeotmal (Warora, Ghugus, Rajur and Ballalpur). The production from each of the areas named is given below :—

Total coal raised in the Central Provinces.

Field.	Period of output.	Production.
Kurasia	1930 to 1933	412,983 tons.
Mohpani	1860 to 1926*	2,000,000 „
Pench Valley	1903 to 1933	9,710,141 „
Shahpur (Betul)	1921 to 1926 †	6,000 „
Warora	1874 to 1906*	2,958,931 „
Ghugus	1920 to 1923†	6,425 „
Rajur	1925 to 1927†	7,064 „
Ballalpur	1904 to 1933	3,546,072 „
	Total output Central Provinces about	18¾ million tons.

* Abandoned. † Stopped producing.

Hyderabad (Deccan) State.

The Lower Gondwana coalfields in the Nizam's Dominions are a south-easterly continuation in the Godavari valley of the Strata included in the Wardha Valley coalfields. The chief coalfields in the Godavari tracts of Hyderabad are Sasti, Tandur, Singareni and Kanala. The production from these areas is shown below :—

Total coal raised in Hyderabad State.

Field.	Period of output.	Production.
Sasti	1920 to 1933	549,132 tons.
Tandur	1931* to 1933	226,189
Singareni	1887 to 1933	21,904,935 „
Chunala (Kanala)	1933	84,447 „
	Total output Nizam's Dominions about	22¾ million tons.

* Included in Singareni for 1931.

Madras Presidency.

Efforts were made between 1891 and 1895 in two areas—Lingala and Ganaparam—in the East Godavari district to open collieries. The raisings from these explorations are shown below :—

Total coal raised in Madras.

Field.	Period of output.	Production.
Lingala	1891*	70 tons.
Ganaparam	1891 to 1895*	3,657 „
	Total output Madras Presidency about	3,750 tons in all.

* Suspended.

Orissa.

There are two working collieries—in the Talcher and Ib River (Rampur) coalfields respectively—in this newly established province. The raisings from these are shown below :—

Total coal raised in Orissa.

Field.	Period of output.	Production.
Talcher	1923 to 1933	922,337 tons.
Ib River	1913 to 1933	893,652 ,,
	Total output Province of Orissa	1,815,989 tons.

Coal Produced from each Coalfield.

Darjeeling district.

Daling Colliery was opened in 1896 and the enterprise abandoned in 1900. During the above period, 7,231 tons of coal were raised (*see* page 49). The details are as follows :—

	Tons.
1896	96
1897	1,356
1898	2,191
1899	2,098
1900	1,490

Mr. Bose calculated 20 million tons of caking coal in area 2¾ miles by three eighths of a mile between the Lisu and Ramthi rivers and 100 million tons in all in two square miles in the same tract. Less than *7,250 tons* have been taken.

Rajmahal Hills.

Coal was raised in the Rajmahal Hills between 1858 and 1863 as follows (27·23 mds.=1 ton) :—

	Maunds.
1858	219,000
1859	757,000
1860	1,234,860
1861	63,935
1862	44,329
1863	300

Coal was again exploited from about 1886, but up to 1890, only 125 tons were raised (Domanpur). In 1890, the output was about 200 tons and production in this small way continued till 1898, when the raisings were 423 tons. The details of production since 1898 are given on pages 58-59. It may be taken that not more than *100,000 tons* have been extracted from all the various coalfields of the Rajmahal hills.

Dr. Ball calculated that 70 square miles of Damuda rocks, comprising the known Rajmahal coalfields, could safely be taken as having five feet of workable coal. This gives a total of 350 million tons, but does not include Damudas underlying the basaltic lavas and no allowance is made for losses in working, etc.

Deogarh (Karon) coalfields.

Only the Jainti area has been exploited. A mine was opened near Madhankata in 1886. Between then and 1889, the total raisings were 24,448 tons. The output for 1890 is given as 35,344 tons, but no figures are shown for the period 1891 to 1894 and it is suspected that they are indicative of closed down mines. From 1895 to 1897, production, if any, would be included under the Santal Pargana coalfields which comprised the Rajmahal hills and part of the Raniganj coalfield north of the Adjai river. Separate returns of the various areas in the Santal Pargana coalfields are given from 1898 and there is no production from Jainti shown.

It is believed that the Jainti field was not re-opened until the outbreak of War in 1914. The detailed production since then is shown on page 62. From the particulars given it appears that the total production from the Jainti coalfield to 1933 has not exceeded *one and a half million tons*, of which barely 100,000 tons were evidently raised before 1898 and this assumes work between 1891 and 1898.

Giridih (Karharbari) coalfield.

This field was exploited in a small way between 1850 and 1857, when perhaps not more than 500 tons in all were raised in it. Between 1858 and 1863, the total production is computed at 35,000 tons (*see* page 68, which figures are based on the conversion of 27·23 maunds to one ton). There were no raisings between 1864 and 1870, when the East Indian Railway was evidently extended to this field. Details of the production between 1871 and 1894

have not been secured, but it is computed that ten million tons were raised in this period.

The annual production of coal from the Giridih coalfield since 1895 to 1933 is shown on page 69 and totals 29,299,992 tons. So that it may be safely taken that not more than *40 million tons* of coal have been raised in the Giridih coalfield. It can be assumed that all this coal has been extracted from the Lower and Upper Karharbari seams. The reserves in these seams in their original condition probably lay between 105 to 125 million tons, *say* 115 million tons intact.

Raniganj coalfield.

It is of historical interest that this coalfield was the first to be opened in India—as far back as 1774—but the production of coal up to 1815 can be regarded as very small. During the period 1815 to 1823, about 400 tons a year appear to have been raised. Between 1824 and 1857, there are no complete details, and some of those which are available are in disagreement; but by 1858, the annual output from Raniganj had attained the 200,000-ton mark. The details for the period 1858 to 1868 are given on page 93. The total production till then (1868) can be taken safely as between 7½ to eight million tons actually raised.

I have been unable to secure the output details for the Raniganj coalfield between 1869 and 1879; but from the particulars available (pages 93-94), the yearly output was about 500,000 tons, or *say* six million tons during these 12 years. There are also no separate returns available for Raniganj between 1880 and 1895 except stray data (*see* pages 94-95). From these data, however, I compute 800,000 tons a year for the period 1880-1889 or eight million tons in total. For 1890-1895, I estimate 1,750,000 tons a year, *i.e.*, 10½ million tons for six years. For 1869 to 1895, therefore, the total production is 24½ million or *say* 25 million tons.

Since 1896, complete returns of the output of coal from the Raniganj coalfield are available (*see* pages 95-97) and for this period, 1896 to 1933, of 38 years the production of coal has been 181,505,997 tons. If we add to this the totals for the periods 1869 to 1895, *i.e.*, 24·5 million tons and 1815 to 1869, *i.e.*, 7·5 million tons, we can safely take the total production of coal from the Raniganj coalfield up to 1932 as roughly *214 million tons*. In this field, the latest estimated reserves of coal are, to a depth of 2,000 feet, 331 million

tons of caking coal, 1,678 million tons of good coal and **6,940 million** tons of inferior coal--total reserves of 7,950 million tons.

Jharia coalfield.

The official production returns for coal from the Jharia coalfield are complete and begin from the year 1897, since when the total raisings to 1933 (*see* pages 111-113) have been 267,550,779 tons or roughly *268 million tons.* This, like that of the Raniganj coalfield, is largely taken from the better grades of coal in the field. The original reserves in the Jharia coalfield, to a depth of 2,000 feet, have been estimated at roughly 4,540 million tons (about 1,000 tons good caking coal, 1,500 good to fair coal and 2,000 tons inferior coal).

Bokaro coalfield.

This field was opened in 1908 (*see* pages 128-129) and the total production to 1933 has been *23,452,162 tons* from East Bokaro. No developments have been made in West Bokaro. The total reserves in East Bokaro are roughly computed at 3,000 million tons (1,000 million tons fair to good caking coal and 2,000 million tons inferior coal) in 15 square miles.

Ramgarh coalfield.

This area was exploited during the ' boom ' period (of high prices) just after the War (*see* page 135). The total production between the opening up of the field in 1919 and the closing down of the mines in 1928 were *25,389 tons.* The coal is of fair to inferior quality.

Karanpura coalfields.

All the coal from this area has been raised from the South Karanpura coalfield which was opened in 1924 (*see* page 149). The total production to 1933 has been *2,872,916 tons.* The total reserves in the South Karanpura coalfield are estimated at 750 million tons much of which appears to be of good to fair quality.

Hutar coalfield.

This field was opened very many years ago and was known as far back as 1779. However, production in a regular way only

began in 1927 (*see* page 151), but due to the prevailing depression in the coal trade, the mines appear to have closed in 1930. During this short period of four years, the total production has only been *1,466 tons.* The coal is of good quality in several areas which have been tested, and reserves up to 32 million tons have been estimated.

Daltonganj coalfield.

The Palamau or Daltonganj coalfield has been worked off and on since 1842. It is impossible to compute the raisings between 1842 and 1899, owing to lack of data; but it is believed that half a million tons were not extracted in this period. Since 1900 and to 1931 (*see* pages 159-160), the production has been *1,465,506 tons,* or *say two million tons* in all.

Talcher coalfield.

This area was explored with great courage and opened in 1923, when a branch line from the Bengal-Nagpur Railway was laid to it. The production has steadily improved since then (*see* page 169), and the total raisings to 1933 have been *922,337 tons.* The field in an area about 22 square miles is thought to contain from 100 to 150 million tons of coal.

Rampur (Ib River) coalfield.

The production of coal from the Ib River (Rampur) coalfield began in 1913 and since then, to 1933 (page 173), has been *893,652 tons.* The coal is of fair to good quality and the reserves in the two square miles property of the Hingir Rampur Coal Co., Ltd., were 14 million tons, and in the coalfield as a whole, quite ten times this amount.

Umaria coalfield.

Coal was first raised in this area in 1884 and an output has been maintained since (*see* pages 187-188). The total production, including a small quantity of coal from the Johilla coalfields in 1898 to 1902, from 1884 to 1933 has been *6,020,989 tons.* The computed original reserves of this coalfield (proved 1¼ square miles, expected four square miles with 20 feet of coal) were 80 million tons.

Johilla coalfield.

A small production is recorded (with that of Umaria) from the Johilla coalfield during the period 1898 to 1902, but it is doubtful if this field will be opened before Umaria is closed.

Sohagpur coalfield.

Coal began to be raised from the Dhanpuri quarries and from the workings of Burhar Colliery in the Sohagpur coalfield in 1921 (*see* page 195). The production has been fairly maintained since, *i.e.*, 13 years to 1933, and in all about *1,291,581 tons* of coal have been extracted.

Kurasia coalfield.

Production from Kurasia and Chirmiri collieries is recorded from 1930 when the line, Bengal-Nagpur Railway branch, from Anupper was opened. The output has gone from 3,517 tons in 1930, to 31,351 tons in 1931, to 113,858 tons in 1932 and to 264,257 tons in 1933—*412,983 tons in all* so far. The reserves are estimated at from 20 to 30 million tons.

Mohpani (Gotitoria) coalfield.

The explorations in the Sitarewa (*Mohpani*) area began about 1860 when early railway communication was expected, but connexion by rail was not established until 1871. The production between 1860 and 1870 is believed to have been less than 4,000 tons. From 1867 to 1891, the production has been given as 310,973 tons (*see* page 255); and up to 1894, the total is probably 400,000 tons since work was begun in 1860. Since 1895, we have a complete record of production to 1927, when the mines were abandoned. During this period of 33 years, the production (*see* pages 255-256) of coal was 1,667,711 tons. Thus in the 66 years that work was carried on at Mohpani and Gotitoria, the total coal raised appears to have been little more than *two million tons.*

Shahpur (Betul) coalfields.

Practically all the production was obtained from three areas—Gurgunda, Mardanpur and Dulhara—during the post-War period 1921 to 1926 (*see* page 259). The total production during these six years was only about *6,000 tons* in all.

Pench Valley (and Kanhan) coalfields.

Regular working was established in the Barkui and Chandameta areas with the construction and opening of the Bengal-Nagpur Railway branch line from Chhindwara in 1903. The Kanhan fields were tapped as late as 1915 by the Great Indian Peninsula Railway from Amla. The output of both tracts are included in the return for the Pench Valley coalfield. The total production since 1903 to 1933, *i.e.*, for 31 years, has been *9,710,141 tons* nearly 8 million tons; and while othercoalfields have shown a diminished output during the past eleven years (1923 to 1933), that of the Pench Valley has doubled.

Warora coalfield.

Production began in 1874 and till the serious fire of 1882 the output was (1874-1881) 163,714 tons. During the period 1882 to 1894, there appears to have been no (available) published production from Warora, but an estimate of 105,000 tons a year is probably a safe guess—giving 1,360,000 tons. From 1895, we have separate details for Warora, until it was abandoned in 1907. During this period, the production (*see* page 303) was 1,435,217 tons. Thus the total coal raised at Warora during the days of its activity were roughly 2,059,931 tons, or *say* roughly *three million tons.*

Yeotmal (Wun) coalfields.

The details here given evidently refer to two distinct areas—Ghugus in the Wardha valley (in Chanda district) for 1920 to 1923, and Rajur in Yeotmal (Wun) for 1925 to 1927. The production during the first (four-year) period was 6,425 tons, and that for the later (three-year) period was 7,064 tons. The whole was produced by the same company as that working at Ballalpur. A small amount of coal was got at Ghugus in 1871-73, but no details are now procurable of the ill-fated Mayo pit.

Ballalpur coalfield.

This area was opened in 1903 before Warora was closed down The production since 1904 to 1933 (*see* pages 312-313) has now totalled *3,546,072 tons, i.e.*, over 3½ million tons. The reserves of coal in a two square mile area about Ballalpur have been computed at 40 million tons, but this is a mere fraction of what is suspected to be a great hidden coalfield to the east of it.

Sasti coalfield.

This tract is really the south-westerly extension of the Ballalpur coal-measures. A colliery was opened at Sasti about 1919 and the output has been recorded since 1920. The total production to 1933 shows *549,132 tons*, *say* half a million tons, as having been raised. A large area of possible coal-bearing strata extends westwards from Sasti.

Tandur coalfield.

A new colliery has been opened at Tandur and since the construction of the railway from Balharshah to Kazipet in 1930 coal has been raised for despatch. The production began in 1931 but was recorded with the output from Singareni. In 1932 the raisings were 126,171 tons and in 1933, 99,718 tons.

Singareni (Yellandlapad) coalfield.

Dr. William King discovered this coalfield in 1872, but coal was raised till 1887 since when a regular output has been maintained. The total production 1887 to 1933 (*see* pages 329-330) has been *21,904,935 tons* in 47 years. The opening up of Tandur and the decline in output at Singareni suggests that this coalfield has passed the period of economic working. All the coal has been taken from the King seam, which was computed to hold 45 million tons, while the field itself probably has reserves of inferior coals which must total more than twice as much again.

Chunala.

The first recorded production from this coalfield in Hyderabad is in 1933 when *84,447 tons* were produced.

Lingala (Madras) exploration.

In 1891, about *70 tons* of good coal were taken out of the coal measures near Lingala on the British side of the Godavari river. It was then computed that the area contain about 12 million tons of coal.

Ganaparam (Madras) area.

This tract, also in the East Godavari district, yielded *3,657 tons* of coal from pits at Rajazompalli between 1891 and 1895. The area about Rajazompalli is estimated to contain roughly 36 million tons of coal.

GENERAL INDEX.

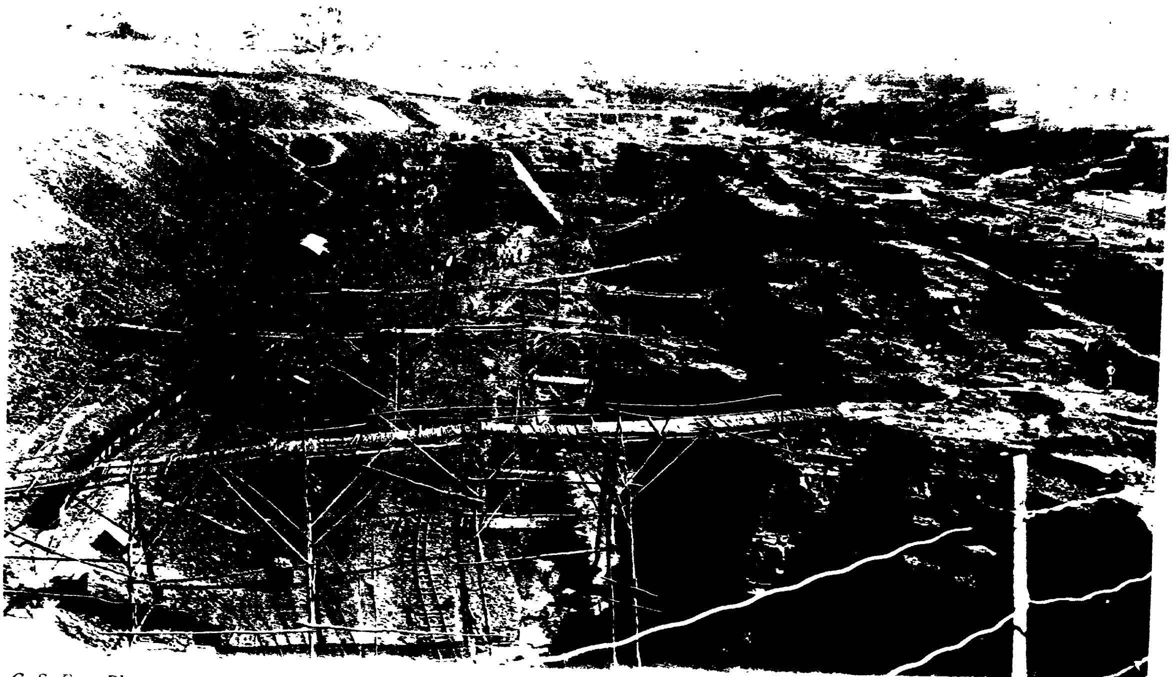
K

U

GEOGRAPHICAL INDEX.

MGIPC—M—VIII-4-12—9-7-34—1,150.

G. S. I, Calcutta.



C. S. Fox, Photo.

DAMAGARIA QUARRY, SHOWING THE 100-FOOT DAMAGARIA SEAM.

G. S. I., Calcutta.

C. S. Fox, Photo. *G. S. I., Calcutta.*

THE CONFLUENCE OF THE DAMODAR WITH THE BARAKAR RIVER, SHOWING THE ELECTRICAL TRANSMISSION LINE AND AERIAL ROPEWAY.

C. S. Fox, Photo. *G. S. I., Calcutta.*

QUARRYING COAL ALONG A FAULT AT BHAURA (BHOWRA COLLIERY).

C. S. Fox, Photo. *G. S. I., Calcutta.*

JOINT RAILWAY QUARRY NEAR BERMO, BOKARO COALFIELD, SHOWING THE 100-FOOT KARGALI SEAM.

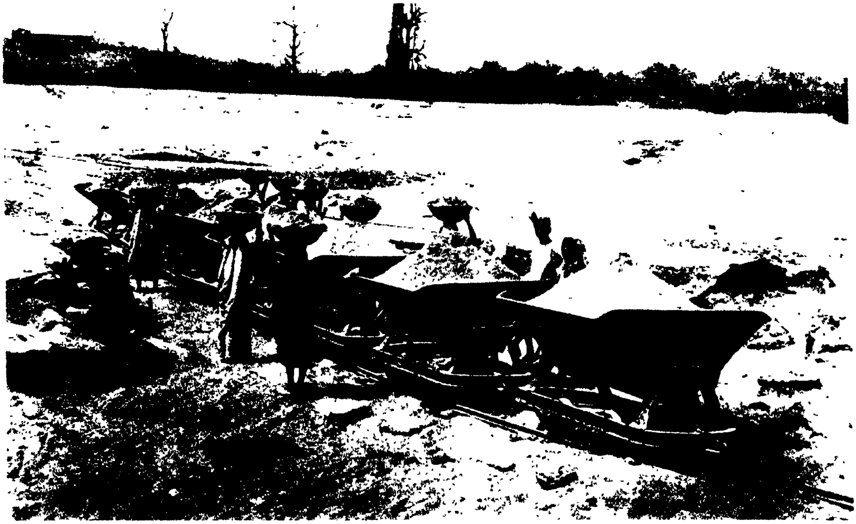
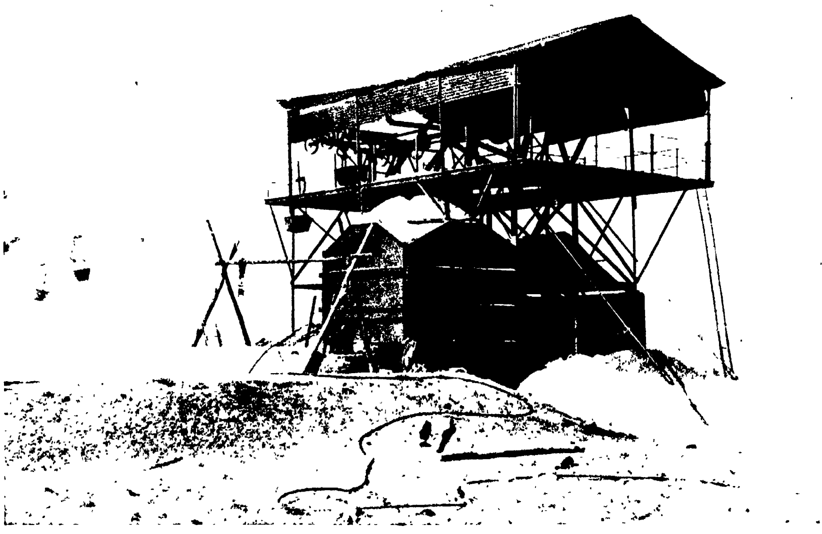


FIG. 1. LOADING SAND IN THE DAMODAR RIVER NEAR AMLABAD.



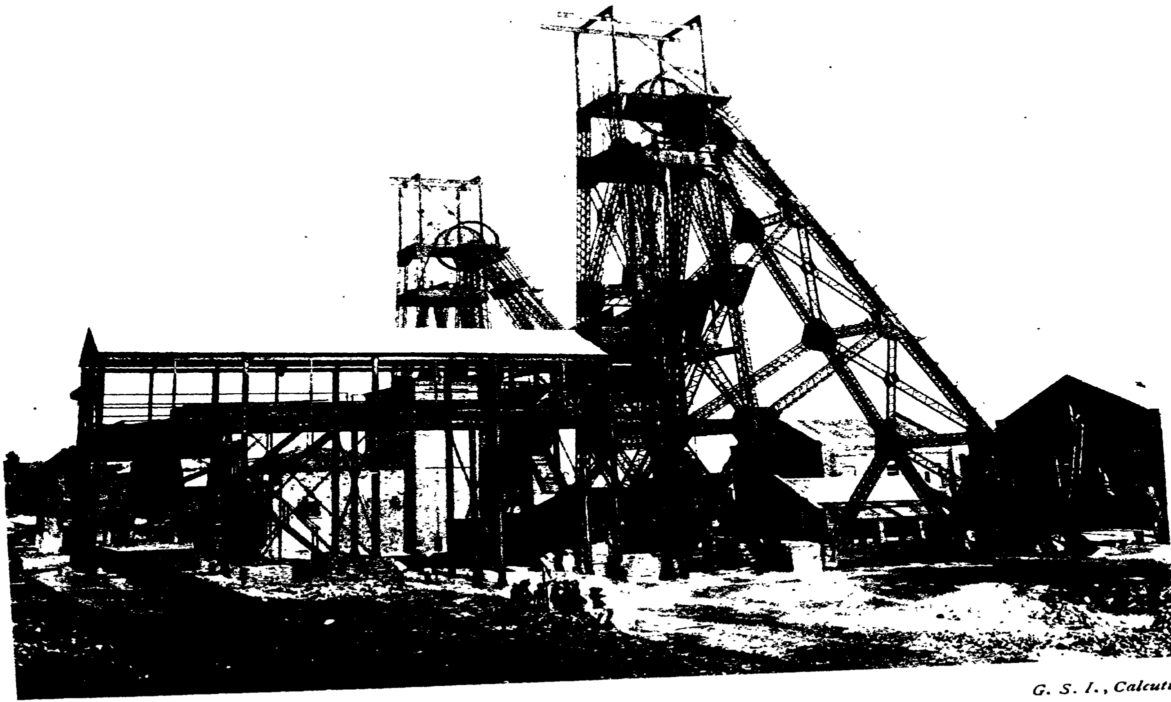
Photographs kindly supplied by J. Mackie, Esq. *G. S. I., Calcutta.*

FIG. 2. SAND BIN AT THE BHOWRA TERMINAL OF THE AERIAL ROPEWAY FROM AMLABAD.

ASSEMBLING SAND FOR HYDRAULIC STOWING AT BHOWRA COLLIERY, JHARIA COALFIELD.

C. S. Fox, Photo. *G. S. I., Calcutta.*

OPEN TYPE COKE-KILNS AT DHORI COLLIERY, BOKARO COALFIELD.



C. S. Fox, Photo. *G. S. I., Calcutta.*

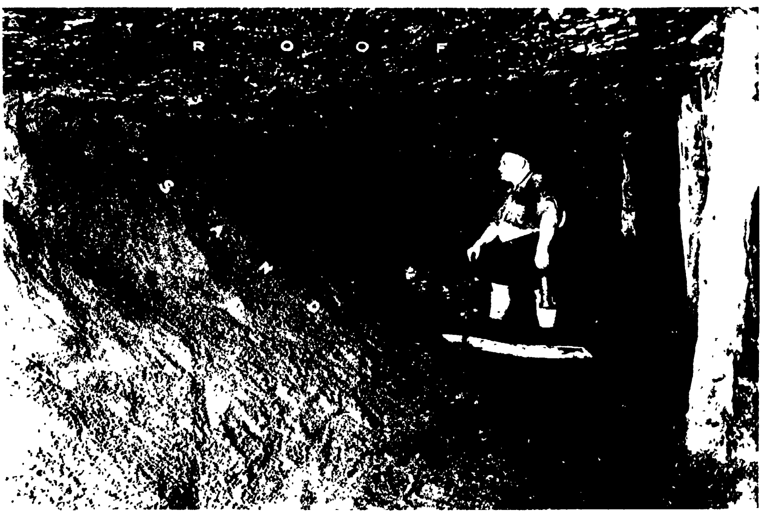
VIEW OF NEW HEAD-GEAR AT JARANGDIH COLLIERY, BOKARO COALFIELD.

C S. Fox, Photo. *G. S. I., Calcutta.*

QUARRY IN THE SIRKA SEAM, SOUTH KARANPURA COALFIELD.

C. S. Fox, Photo. *G. S. I., Calcutta.*

OPENING AN INCLINE INTO THE SIMANA SEAM AT BHURKUNDA COLLIERY, SOUTH KARANPURA COALFIELD.



Photographs kindly supplied by R. Husband, Esq. *G. S. I., Calcutta.*

SAND STOWING OPERATIONS AT GOTTITORIA NEAR OLD MOHPANI.

THE UPPER FIGURE SHOWS SAND AND WATER BEING MIXED AND FED DOWN THE HOPPER INTO PIPES LEADING TO VARIOUS POINTS IN THE COLLIERY.

THE LOWER FIGURE SHOWS SAND BEING FILLED INTO ONE OF THE GOAVES.